National Electric Power Company
Hashemite Kingdom of Jordan

Project for the Study on the Electricity Sector Master Plan in the Hashemite Kingdom of Jordan

Final Report

February 2017

Japan International Cooperation Agency (JICA)

JERA Co., Inc.
Nippon Koei Co., Ltd.

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ABREVIATIONS

Word	Original
AAAC	All Aluminum Alloy Conductor
ACSR	Aluminum Cable Steel Reinforced
ACSS	Aluminum Conductor Steel Supported
ADB	Asian Development Bank
ADC	Aqaba Development Corporation
AGC	Automatic Generation Control
APCO	Attarat Power Company
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
ATPS	Aqaba Thermal Power Station
bbl	Barrel
B/C	Buyer's Credit
BEMS	Building Energy Management System
B/L	Bank Loan
BOD	Biochemical Oxygen Demand
BSP	Bulk Supply Point
BTU	British Thermal Unit
CAPEX	Capital Expense
CBD	Convention on Biological Diversity
CCGT	Combined Cycle Gas Turbine
CCR	Central Control Room
CCS	Carbon Capture and Storage
CEGCO	Central Electricity Generation Company
CEM	Certified Energy Manager
CFB	Circulation Fluidized Bed Boiler
CFL	Compact Fluorescent Lamp
CIRR	Commercial Interest Reference Rate
COD	Commercial Operation Date
COD	Chemical Oxygen Demand
CRM	Carbon Reduction Manager
CWEEL	Council on Women in Energy & Environmental Leadership
DESCO	Dhaka Electric Supply Company Limited
DLC	Daily Load Curve
DLS	Department of Lands and Surveys
DO	Diesel Oil
DOE	Department of Environment
DR	Demand Response
DSM	Demand Side Management
DZA	Development Zone Authority
D/L	Distribution Line
ECCJ	Energy Conservation Center Japan
EDCO	Electricity Distribution Company

EE	Energy Efficiency
EEP	Energy Efficiency Project
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Regulations
EIB	European Investment Bank
EMMP	Environmental Management and Monitoring Plan
EMRC	Energy & Mineral Regulatory Commission
EPC	Engineering, Procurement and Construction
EPL	Environmental Protection Law
ERC	Electricity Regulator Commission
ESC	Environmental and Social Considerations
ESCB	Energy Sector Capacity Building
FSRU	Floating Storage and Regasification Unit
F/S	Feasibility Study
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
GOJ	Government of Jordan
GT	Gas Turbine
HEMS	Home Energy Management System
HEPA	High-Efficiency Particulate Air Filter
HFO	Heavy Fuel Oil
HTLS	High-Temperature, Low-Sag
HTPS	Hussein Thermal Power Station
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome
IBA	Important Bird and Biodiversity Areas
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICZN	Integrated coastal zone Management
IDECO	Irbid District Electricity Company
IEA	International Energy Agency
IEE	Initial Environmental Examination
IGV	Inlet Guide Vane
IMF	International Monetary Fund
IPP	Independent Power Producer
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature and Natural Resources
JAEC	Jordan Atomic Energy Commission
JBIC	Japan Bank for International Cooperation
JCC	Joint Coordinating Committee
JD	Jordan Dinar
JEC	Jordan Energy Chapter
JEDCO	Jordan Enterprise Development Corporation
JEPCO	Jordan Electricity Power Company
JICA	Japan International Cooperation Agency

JISM	Jordan Institution for Standards and Metrology
JNPC	Jordan Nuclear Power Company
JNR	Japanese National Railways
JREEEF	Jordan Renewable Energy and Energy Efficiency Fund
JSCs	Joint Service Councils
JVA	Jordan Valley Authority
KEC	Kingdom Electricity Company
KEPCO	Korean Electric Power Corporation
LACP	Land Acquisition & Resettlement Plan
LAL	Land Acquisition Law
LC	Low Curie
LCC	Life Cycle Cost
LDC	Load Duration Curve
LED	Light Emitting Diode
LFC	Load Frequency Control
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LOLP	Loss Of Load Probability
LPG	Liquefied Petroleum Gas
LV	Low Voltage
LULUCF	Land Use, Land Use Change and Forestry
MEA	Metropolitan Electricity Authority (of Thailand)
MEDA	Mediterranean countries (French; MEsures D'Accompagnement)
MEMR	Ministry of Energy & Mineral Resources
METI	Ministry of Economy, Trade and Industry
MMscfd	Million standard cubic feet per day
MoA	Ministry of Agriculture
MoEnv	Ministry of Environment
MoF	Ministry of Finance
MoH	Ministry of Health
MoL	Ministry of Labor
MoMA	Ministry of Municipal Affairs
MoPIC	Ministry of Planning and International Cooperation
MoTA	Ministry of Tourism and Antiquities
MOU	Memorandum of Understanding
MoWI	Ministry of Water and Irrigation
MTrs	Multi-Transformer System
MV	Medium Voltage
NCC	National Control Center
NDT	Non Destructive Testing
NEAP	National Environmental Action Plan
NEEAP	National Energy Efficiency Action Plan
NEPCO	National Electric Power Company
NERC	National Energy Research Center

NES	National Environmental Strategy
NGO	Non-Governmental Organization
NPC	National Power Corporation
NRA	Natural Resource Authority
NPP	Nuclear Power Plant
NTL	Non-Technical Loss
OA	Office Automation
OECD	Organization for Economic Co-operation and Development
OPEX	Operating Expense
OSPP	Oil Shale Power Plant
O&M	Operation and Maintenance
PAP	Project Affected Person
PCE	Prime Cost for Electricity Power
PPA	Power Purchase Agreement
PPPs	Policies, Plans and Programs
PR	Public Relations
PSALM	Power Sector Asset and Liability Management Corporation
PV	Photovoltaics
QAIA	Queen Alia International Airport
RE	Renewable Energy
REP	Renewable Energy Professional
RPF	Resettlement Policy Framework
ROA	Return on Asset
RoR	Rate of Return
RSCN	Royal Society for Conservation of Nature
R/D	Record of Discussion
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SC	Super Critical
SCA	Special Conservation Area
SCADA	Supervisory Control and Data Acquisition
scf	Standard Cubic Feet
SCGT	Simple Cycle Gas Turbine
SEA	Strategic Environmental Assessment
SEACC	Strategic Environmental Assessment Consultative Committee
SEPCO	Samra Electricity Power Company
SMAP	The Short and Medium-term Priority Environmental Action Programme
SS	Suspended Solid
ST	Steam Turbine
TDS	Total Dissolved Solid
TL	Technical Loss
TNSP	Transmission Network System Provider
TSO	Transmission System Operator
TSP	Total Suspended Particular

TTHM	Total Trihalomethane
T/L	Transmission Line
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USC	Ultra Super Critical
VOCs	Volatile Organic Compounds
WAJ	Water Authority of Jordan
WB	World Bank
WG	Working Group
WHO	World Health Organization
WTI	West Texas Intermediate
XLPE	Cross - linked Polyethylene

Chapter 1 **Preface**

1.1 Background

In Hashemite Kingdom of Jordan, consumption of energy is increasing as a result of economic growth in recent years. Particularly since 2011, the consumption has increased rapidly due partly to the effects of a massive inflow of refugees fleeing from the conflict in Syria. Imported natural gas and petroleum account for about 98% of the country's primary energy. The country has been dependent on cheap natural gas imported from Egypt. However, the pipeline for supplying natural gas was damaged repeatedly in the Sinai Peninsula by bombings, and the supply of natural gas has declined sharply. Consequently, the country was forced to import a large quantity of diesel fuel as an alternative source of energy. The expenses of importing fuel and increased subsidies that were necessitated have been squeezing the finances of government of Jordan, and this problem has become a destabilizing factor for the country's energy supply and management of its national economy.

In Hashemite Kingdom of Jordan, advances have been made in reducing power transmission losses, in improving power plant operation and maintenance, etc. In addition to these efforts, however, it has become a pressing issue for the country to come up with new multifaceted measures that incorporate examination of the optimal makeup of energy sources including long-term strategies for securing fuel supply, drafting of a power system plan anticipating huge introduction of renewable energy sources, promotion of energy saving, etc.

The latest electricity sector master plan in Jordan is the one approved by the Energy and Minerals Regulatory Commission in 2008, and there is an ardent chorus of people calling for a new master plan to be formulated that is based on both the prospect of securing long-term energy supply that takes the current conditions into account and on policies for the power sector. Against this background, Jordan's authority has asked for cooperation from Japan, who is also heavily dependent on imports for its primary energy and who has experience in these issues including know-how on developing a management structure for periodically revising master plans of this kind.

In response to this request, a survey for formulating a detailed plan was conducted in August 2014, and a record of discussion (hereinafter referred to as "R/D") was signed between Jordan's authority and the Japanese side at JICA in October. A study team is organized by Japan International Cooperation Agency (hereinafter referred to as "JICA") for the purpose of project formulation on "the Project for the Study on Electricity Sector Master Plan in the Hashemite Kingdom of Jordan" (hereinafter referred to as "Study").

1.2 Objectives of this study

Objective 1: Formulation of the electrical sector master plan from 2015 to 2034

Objective 2: Conduction of technical transfer concerning a review of the master plan

1.3 Study schedule

The entire schedule for the study and the overall flow of the study are as shown in Figure 1.3-1 and Table 1.3-1.

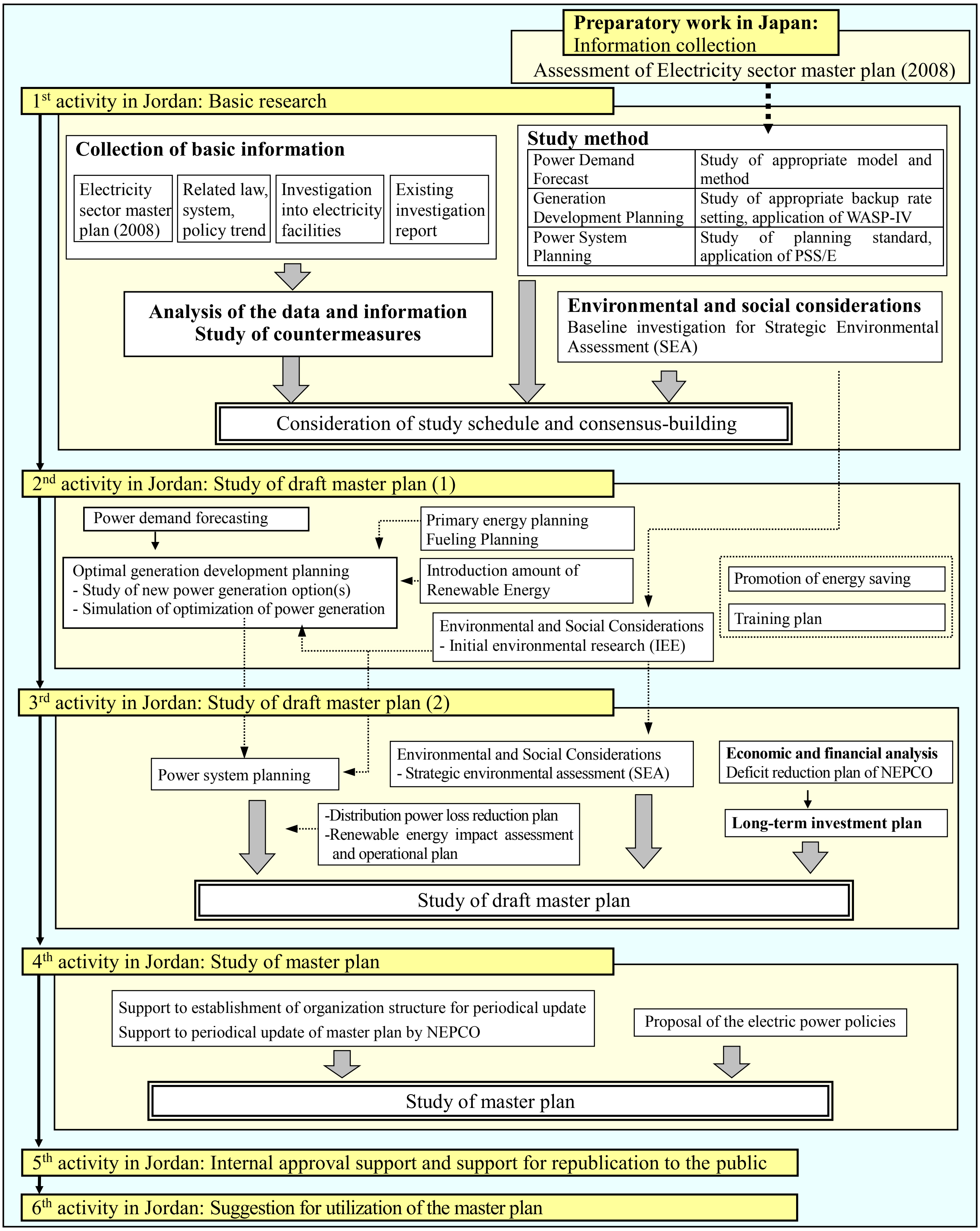


Figure 1.3-1 Study Schedule

Table 1.3-1 Overall flow of the study

Fiscal Year	2014			2015												2016										
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
Study in Jordan			1st activity				2nd activity				3rd activity					4th activity				5th activity					6th activity	
Work in Japan		Preparatory work			1st work		(Ref.)Ramadan period		2nd work				3rd work					(ref.) Ramadan Period		4th work			5th work			

Contents of Work in Japan / Contents Of Work in Jordan

Basic research

Preparatory work
1) Preparation of the Study plan
2) Creation and submission of the Inception Report

1st activity in Jordan
1) Explanation of the Inception Report
2) Support for establisument of the Joint Coordination Committee (JCC)
3) Support for establishment of the Working Groups (WG)
4) Support for holding the 1st seminar
5) Holding the 1st seminar for Japanese affiliated companies
6) Collection of related information and data
7) Assessment and review on methodology of power demand forecast
8) Discussion on methodology of Generation development planning
9) Collection of baseline data about condition of SEA
10) Investigation and analysis of electricity facilities

Study of Draft Master Plan

1st work in Japan
1) Study of techniques and experiences of Japan

2nd Activity in Jordan
1) Study of Electricity Demand Forecast
2) Study of the Primary Energy Plan
3) Study of optimal generation development plan
4) Study of power system plan
5) Study of power system operation plan
6) Study of reduction of distribution loss
7) Study of measures for reducing NEPCO's accumulated deficit
8) Technology transfer regarding determination of the bulk-sale prices
9) Study of environmental and social considerations
10) Study of NEPCO's training plan
11) Study of electric power policy in Jordan

2nd work in Japan
1) Creation and submission of the Progress Report
2) Holding a LNG training

3rd Activity in Jordan
1) Support for holding the 2nd JCC
2) Support for holding the 2nd seminar
3) Proposal on optimal generation development plan
4) Proposal on draft power system plan
5) Proposal on draft power system Operation Plan
6) Proposal on measures for reducing distribution loss
7) Proposal on measures for energy saving
8) Review of human resource development system
9) Study of environmental and social considerations
10) Study of the electric power policy in Jordan

【Holding workshops 】
- Workshop of the human resource development
- Workshop of the energy saving

Study of Master Plan

3rd work in Japan
1) Holding master plan training
2) Drafting a manual for periodical update of the master plan
3) Drafting the Interim Report

4th activity in Jordan
1) Introduction of and discussion on the Interim Report
2) Support to periodic update of the master plan periodically
3) Support for holding the 3rd JCC and the 4th JCC
4) Technical Workshop

4th work in Japan

Drafting the Final Report

5th activity in Jordan
1) Support for holding the 5th JCC
2) Support for holding the 3rd seminar
3) Support for approval and opening of the master plan to the public

Approval of Master Plan

5th work in Japan

Submission of the Final Report

6th activity in Jordan
1) Follow-up for the final report
2) Suggestion for utilization of the master plan

Study in Jordan			1st activity				2nd activity				3rd activity					4th activity				5th activity					6th activity	
Work in Japan		Preparatory work			1st work		(Ref.)Ramadan period		2nd work				3rd work					(ref.) Ramadan Period		4th work			5th work			
Month	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
JCC / Seminar / Work Shop			△ 1st JCC	△ 1st Seminar							2nd JCC △ 2nd Seminar △ Energy saving WS △	△ Human resource development WS				△ 3rd JCC		△ 4th JCC △ Technical training WS		△ 5th JCC △ 3rd Seminar						
Seminar in Japan									LNG training				Master plan training (1)		Human resource training		Master plan training (2)									
Report		△ Inception								△ Progress					△ Interim					△ Draft Final						△ Final

1.4 JICA study team and counterpart

(1) Joint Coordination Committee (JCC) establishment support

The study team supported the establishment of JCC constituted of MEMR, EMRC, Ministry of Finance, Ministry of Environment, Jordan Atomic Energy Commission in addition to NEPCO of the main counterpart, and built the operation system so that the comprehensive master plan could be formulated regularly after this study. Figure 1.4-1 and Table 1.4-1 shows organization chart and the JCC members.

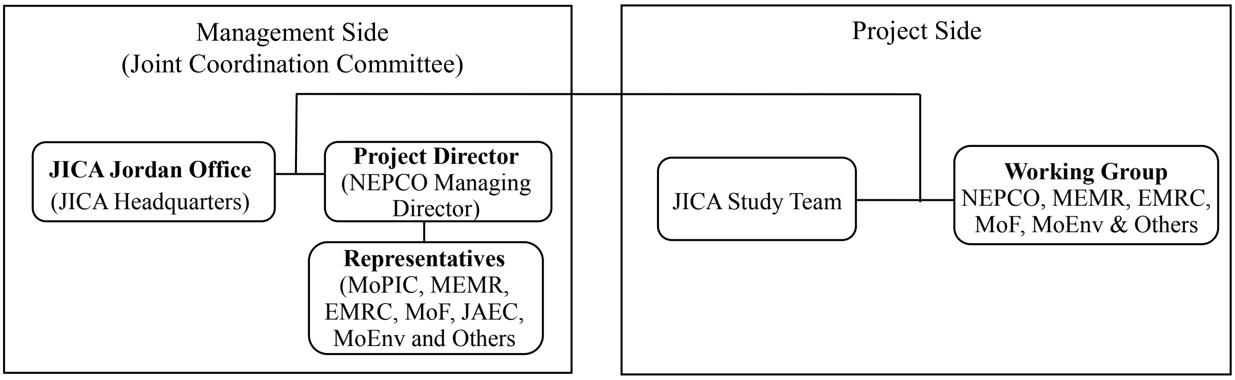


Figure 1.4-1 Project Organization Chart

Table 1.4-1 JCC Members

Name	Organization	Position
Eng. Abdelfattah Aldaradkeh	NEPCO Managing Director	Project Director
Mr. Shokichi Sakata	JICA Jordan Office Chief Representative	
Eng. Ali Suleiman Abadel-Qader Hamaideh	NEPCO Managing Director Assistant for Operation & Planning (from May, 2016)	Project Manager
Eng. Amani Azzam	NEPCO Managing Director Assistant for Operation & Planning (until Apr, 2016)	Project Manager
Eng. Mohmmad Abu Zarour	NEPCO Power System Planning Department Manager	Member
Eng. Muwafaq Humaidet	NEPCO Operational Studies Department Manager	Member
Eng. Feda Jaradat	MoPIC	Member
Ms. Norma Al- Hersh	MoF	Member
Eng. Izzat Abu Humra	MoEnv	Member
Eng. Fariba Hosseini	MEMR	Member
Eng. Wijdan AlRabadi	EMRC	Member
Meqdad A.Qadous, M.A	EMRC	Member
Dr. Sufian Bataenah	MEMR	Member
Eng. Bahjat Aulimat	JAEC	Member

(2) Organization of the Working Group

Table 1.4-2 Working Group Members

WG	Jordan Counterparts	JICA Study Team
Power Demand Forecast	Team leader:Amin Al-Zaghal (NEPCO) Wafa Bakri (MEMR) Hanin Al-Souri (NEPCO) Salah Alaween (NEPCO) Alaa Abu-taleb (NEPCO) Ina'm Alramahi (NEPCO)	Team leader:Akihisa Manita
Generation Development Planning	Team leader: Mohammad Abu-Zarour (NEPCO) Alaa Al-khatib (EMRC) Alaa Abu-Taleb (NEPCO) Emad Abu-Lihye (NEPCO) Mohammad Al-Kilani (NEPCO) Faisal Abu Zaid (NEPCO) Mohammad Obeidat (JAEC)	Team leader:Yoshitaka Saito Norio Iwai Hiroshi Ozawa Tomohiro Kato Mitsuhiro Watanabe Shinjiro Okuzawa
Power System Planning	Team leader:Muwafaq Hmeidat (NEPCO) Bushra Abadi (MEMR) Khaldoun Habahbeh (EMRC) Maysoon Rawabdeh (NEPCO) Mamoun Momani (NEPCO) Mazen Nabulsi (NEPCO) Mahmoud Batayneh (NEPCO) Ateka Aburrub (NEPCO) Ahmad Tahseen (NEPCO) Omar Al-Qdah (NEPCO) Afif Khouri (NEPCO) Ibrahim Hasan (NEPCO) Manhal Moura Sayedh (JEPCO)	Teamleader:Kazunori Ohara Yoshihide Takeyama Takahiro Suzuki Tomohide Kato
Environmental and Social Considerations	Team leader:Emad Musa (MoEnv) Ahmad Al-Dohni (NEPCO) Murad Al-Omari (NEPCO)	Team leader:Shinjiro Okuzawa Yoshitaka Saito Hiroshi Ozawa
Economic and Financial Analysis	Team leader:Kamel Al-Atout (NEPCO) Mudar Sarah (NEPCO) Hasan A.H. Nassar (NEPCO) Anas Abn Rayyan (NEPCO) Zaid Ammari (MoF)	Team leader:Masayasu Ishiguro

(3) JICA Study Team

Table 1.4-3 JICA Study Team Member

No	Name	Assignment
1	Mr. Yoshitaka SAITO	Team Leader/Power Development Planning
2	Mr. Kazunori OHARA	Power System Planning
3	Mr. Norio IWAI	Fueling Supply Planning/Primary Energy Planning
4	Mr. Akihisa MANITA	Power Demand Forecast
5	Mr. Masayasu ISHIGURO	Economic and Financial Analysis/Tariff System
6	Mr. Shinjiro OKUZAWA	Environmental and Social Considerations
7	Mr. Yoshihide TAKEYAMA	Power System Operation Planning
8	Mr. Hiroshi OZAWA	Generation Development Planning
9	Mr. Tomohiro KATO	Power Development Analysis
10	Mr. Takahiro Suzuki	Distribution Planning
11	Mr. Tomohide KATO	Energy Saving
12	Mr. Hiroshi KURAKATA	Electric Power Policy
13	Mr. Mitsuhiro WATANABE	Thermal Power facility (from Jul, 2015)
-	Mr. Shunichiro YASUDA	Thermal Power facility (until Jun, 2015)
14	Mr. Toshitaka YOSHIDA	Transmission Line facility
15	Ms. Mina KOBAYASHI	Training Planning(from Jan, 2016)
-	Ms. Yumiko MUKOHARA	Training Planning (until Dec, 2015)

(4) JCC Meeting

JCC Meetings were held totally 5 times. Meeting records are as follows.

Table 1.4-4 JCC meeting record

	Date	Content	Participants
1st	March 2, 2015	JICA study team and JCC member confirmed the outline of study.	NEPCO, EMRC, MEMR, MoF, MoPIC, JNPC, MoEnv, JAEC, Embassy of Japan, JICA
2nd	November 10, 2015	JICA study team reported whole study result of power demand forecast and also reported progress study of generation development plan, power system plan, economic and financial analysis and environmental and social considerations	NEPCO, EMRC, MoEnv, MoPIC
3rd	April 10, 2016	JICA study team suggested optimal generation development plan and future power system plan.	NEPCO, MEMR, EMRC, JICA
4th	May 29, 2016	JICA study team reported progress optimal generation development plan and future power system plan.	NEPCO, MEMR, JICA
5th	August 30, 2016	JICA study team reported study result of optimal generation development plan, power system plan and economic and financial analysis based on the draft final report.	NEPCO, MEMR, MoPIC, MoEnv, JICA

Chapter 2 **Primary Energy Policy**

2.1 Current Situation of Primary Energy

The Hashemite Kingdom of Jordan had been imported crude oil mainly from Iraq with which Jordan had historically deep relationship. At the beginning of 21-st century, Jordan imported inexpensive crude oil from Iraq through the Oil-for-Food Programme (1995~2003) by United Nations for the development of her economic progress.

At the end of this program in 2003, Jordan changed imported fuel from crude oil to natural gas by Egypt because purchase cost of natural gas from Egypt was lower than oil cost through the international market.

However total amount of imported natural gas in Jordan in 2013 became insufficient because destruction of Arab-pipeline had occurred several times and the demand of natural gas in Egypt itself became larger.

Under the circumstances, government of Jordan had to procure crude oil and natural gas from the other resources through the international spot market, and it made Jordan's financial condition severe.

Table 2.1-1 shows current energy balance in Jordan. The primary energy resources produced in Jordan are only crude oil, natural gas and renewable energy. But the amount of them accounts for only 3% of total amount of primary energy supply in Jordan and primary energy self-sufficiency of Jordan is very low. Therefore, Jordan has to depend on the import of crude oil, natural gas and so on from neighboring countries for almost of primary energy resources of it. This shows that the energy supply and demand structure of Jordan is extremely vulnerable.

Table 2.1-1 Energy Balance in Jordan (2013)

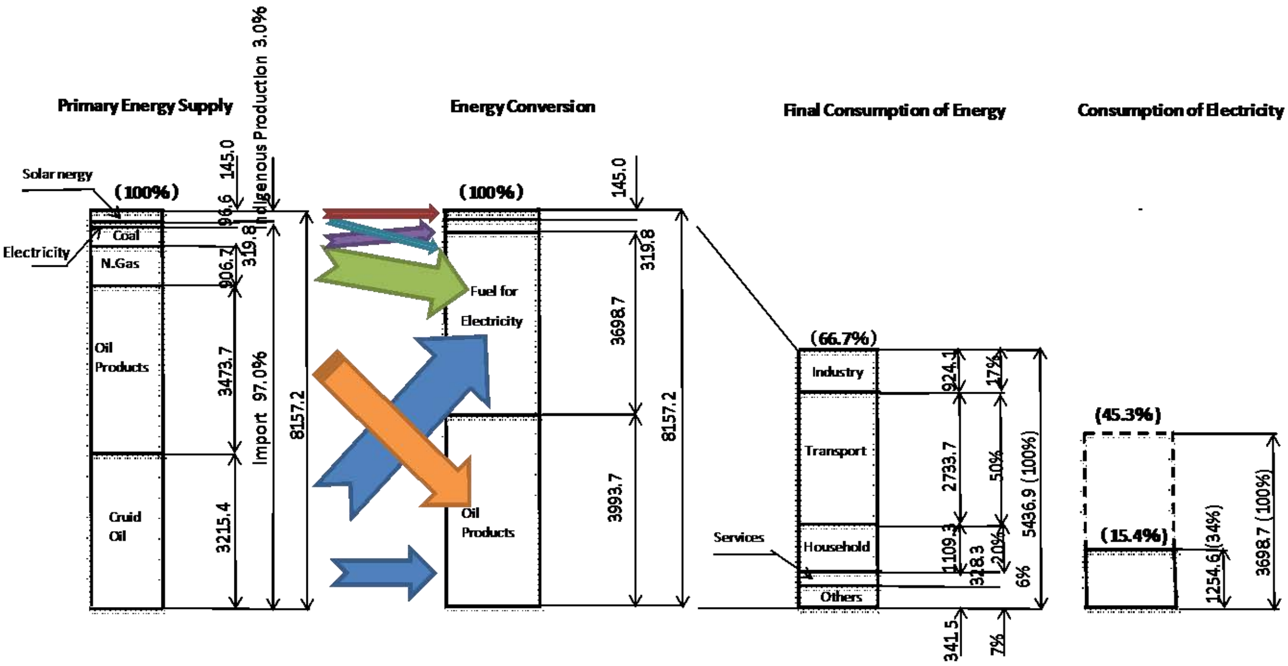
[Unit :1,000TOE]

Sector	Cruid Oil	Fuel Oil	Diesel	Gasoline	LPG	Kerosene	Jet Fuel	VR	Other	Total Oil	Coal	Coke	L Coke	N.Gas	Electricity	Solar Energy	Total Energy
Indigenous Production	0.8									0.8				111.5	16	145	273.3
Import	3173.4	662.6	1702.1	536.3	310.9		27.9	32		6445.2	203.9	106.9	9	795.2	95.3		7655.5
Export										0					14.7		14.7
Bunkers		4.4	2.7				0.8			7.9							7.9
Stoch Changes	-41.2	-71.6	-82.6	-12.1	-6.2	-29.8	-4.3		-3.2	-251							-251
Primary Energy Supply	3215.4	729.8	1782	548.4	317.1	29.8	31.4	32	3.2	6689.1	203.9	106.9	9	906.7	96.6	145	8157.2
Oil Sector	-3215.4	870	998.4	690.6	87.1	35.2	337.2		96.3	-100.6							-100.6
Electricity		-1287.1	-1408.3							-2695.4				-906.7	1454.4		-2147.7
Transp. & Dist.Losses										0					-203.5		-203.5
Cons.Energy Supply		-155.8	-3.7						-46.6	-206.1					-60.2		-266.3
Final Energy Consump.	0	156.9	1394.9	1239	404.2	65	368.6	32	52.9	3713.5	203.9	106.9	9	0	1254.6	145	5436.9
Industry		139	118.2		10.6			32		299.8	203.9	106.9	9		304.5		924.1
Transport		4.4	1117.8	1243			368.5			2733.7							2733.7
Household			71.3		314.1	65.1				450.5					538.8	120	1109.3
Services			66.2		29.4					95.6					207.7	25	328.3
Others		13.7	21.4		50					85.1					203.6		288.7
Non-Energy use									52.8	52.8							52.8
Statistical Differences	0	-0.2	0	-4	0.1	-0.1	0.1	0	0.1	28	0	0	0	0	0	0	32

Source: Energy 2014 Facts & Figures: MEMR

Outline of the flow from Primary Energy to Secondary Energy in Jordan is shown in Figure 2.1-1.

(Primary Energy) (Secondly Energy) [Unit; 1,000TOE]



Source: JICA Study Team

Figure 2.1-1 Outline of the Flow from Primary Energy to Secondary Energy in Jordan (2013)

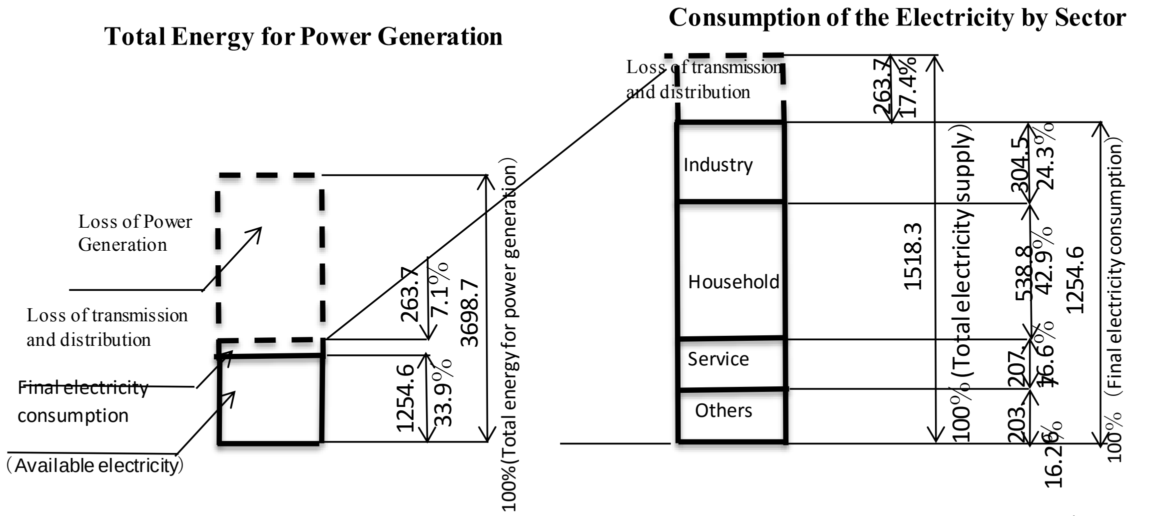
Imported crude oil was refined and processed into petroleum products such as fuel oil, diesel oil, gas, LPG, kerosene and jet fuel. About 40% of petroleum products including imported one are used as a fuel for electric power generation. Almost all of natural gas is used only for a fuel for electric power generation.

Primary Energy resources are consumed as fuel for electric power generation, vehicles, industry and household. All the final consumption of the energy would be two third of primary energy supply and remaining one third would be lost in the process of the refinery and power generation.

When focusing on the contents of the final consumption of energy, 50% of the consumption would be occupied by the transportation and traffic sector, 20% of household sector, 17% of industry and 6% of service sector.

Figure 2.1-2 shows the consumption of electricity as a secondary energy in Jordan.

17.4% of the total energy which is changed to the electricity would be lost in the process of transmission, distribution and consumed for power generation.



Source: JICA Study Team

Figure 2.1-2　Consumption of secondly energy of electricity

2.2 Policy and Challenges

Energy security, economic efficiency and adaptation to the environment should be basic issues in considering the policy in the energy sector.

2.2.1 Energy Security

As mentioned before, the self-sufficient ratio of primary energy of Jordan is very low and 97% of primary energy is depending on the import from abroad.

Therefore in order to secure energy resources, it is indispensable to overcome the following issues.

1) Use of domestic fuel resources

In order to increase an energy self-sufficiency ratio, improve the dependent ratio of local energy resources, development and utilization of domestic energy resources should be promoted as much as possible. Concretely the potential of natural gas, shale oil, renewable energy such as solar power and wind power should be utilized to the maximum.

2) Diversification of the energy resources

Since Jordan cannot but depend on the imported energy resources from abroad, it is necessary to take masures for the diversification of energy resources to reduce the risks of energy supply.

As for the secondary energy occupying about 45% of primary energy supply, the most suitable power supply structure should be established taking economic efficiency into consideration. (the most suitable power supply structure composed of atomic power, shale oil, gas combined and others)

3) Diversification of the importing countries of energy resources

As mentioned article 2) above, since Jordan cannot but depend on the import energy resources from abroad, it is necessary not to rely too much on the specific region or country. And it is necessary to diversify the import countries of energy resources to reduce the risks of energy supply.

4) Storage of the energy resources

For the emergency of the energy supply, it is necessary to store the energy resources taking necessary time to look for a new importing country of energy resources into consideration.

2.2.2 Economic Efficiency of the Energy Supply

The economic effectiveness of the energy supply has a big influence on industrial sector of Jordan in light of international competitiveness and on the life level of Jordanian nation.

It has to aim to establish the strong structure of energy supply that supports the economic growth and at the same time to formulate the affluent society with the international competitiveness that reduces the supply cost of energy resources as much as possible.

It is necessary to promote the following policies in order to realize the above mentioned society.

1) Effective use of energy (for example: especially in the transportation and traffic sector)
2) To promote the energy conservation (for example: the energy saving in the industrial sector)
   It can be said in the secondary energy (electricity) as follows.
3) To establish the most economic and effective composition of power supply
4) To improve the efficiency of thermal power plant
5) To reduce the loss of transmission and distribution network
6) To promote energy conservation activities (save the energy in the household and industry sector)
7) To restrain the peak demand of the electricity by the demand side management
8) Effective use of pumping up and distribution of the water for agriculture, industry and drinking

2.2.3 Adaptation to the Environment

As mentioned in (1) and (2) above, Jordan will aim at the society that supplies energy effectively and stably and this society should be realized with taking adaptation to the environment into consideration.

Specifically, it is necessary to promote the environmental policy considering the measures against global warming as follows.

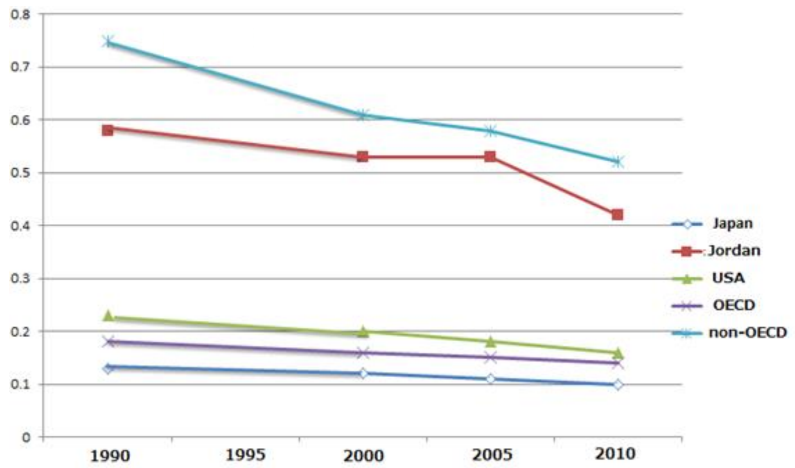
1) To utilize renewable energy (especially in the wide desert area)
2) To restrain the greenhouse gas emission in all levels

2.3 Recommendation on the Energy Policy

2.3.1 To realize more effective and high productivity society

As mentioned in the chapter before, the dependent ratio of domestic energy resources of Jordan is very low and almost of primary energy should be imported from abroad.

Therefore Jordan has to aim at a country having more effective use of energy and highly productivity by seeking rational use of energy and energy conservation. Following Figure 2.3-1 shows the comparison of primary energy which produces unit GDP between Jordan and other countries.



Source: JICA Study Team

Figure 2.3-1 TPES/GDP (toe per thousand USD)

When compared with other non-OECD countries, Jordan can be recognized as a country which conducts effective production activities, but there is still a great difference compared to OECD countries. Jordan has to aim at a country with more efficiency and higher productivity in its economy so that it can achieve further development of economy in the future.

And it is important to ensure the consistency between an industrial policy that aims at nurturing industries with higher productivity and energy conservation and an energy policy.

2.3.2 Improvement of the energy efficiency and Promotion the energy conservation

In order to realize the high efficient and more productive country, Jordan has to improve the energy efficiency and to promote the energy conservation in the industrial and household sector.

We would like to recommend establishing the special department to support these activities.

Through this department, energy management system should be established to improve the energy efficiency and to promote the energy saving in the whole country.

2.3.3 To secure the consistency between long term plans

The long term plan should be revised periodically reflecting the change of the situation.

Ministry of Energy and Natural Resources made the long term plan as “Master Strategy of Energy Sector” including all energy industries in Jordan. It was revised in 2015 aiming the target year of 2025. On the other hand NEPCO is now drafting “the Master plan of Electric Power Sector” with the target year of 2035. These long term plans are not harmonized in the target year.

It is necessary to adjust the contents of the long term plan such as the target year periodically under the common rule. And it is very important to set up and to achieve the objectives of the long term plan with the cooperation of all stakeholders such as petroleum industry, gas industry and electric power industry.

2.3.4 Installation of renewable energy taking into consideration system condition

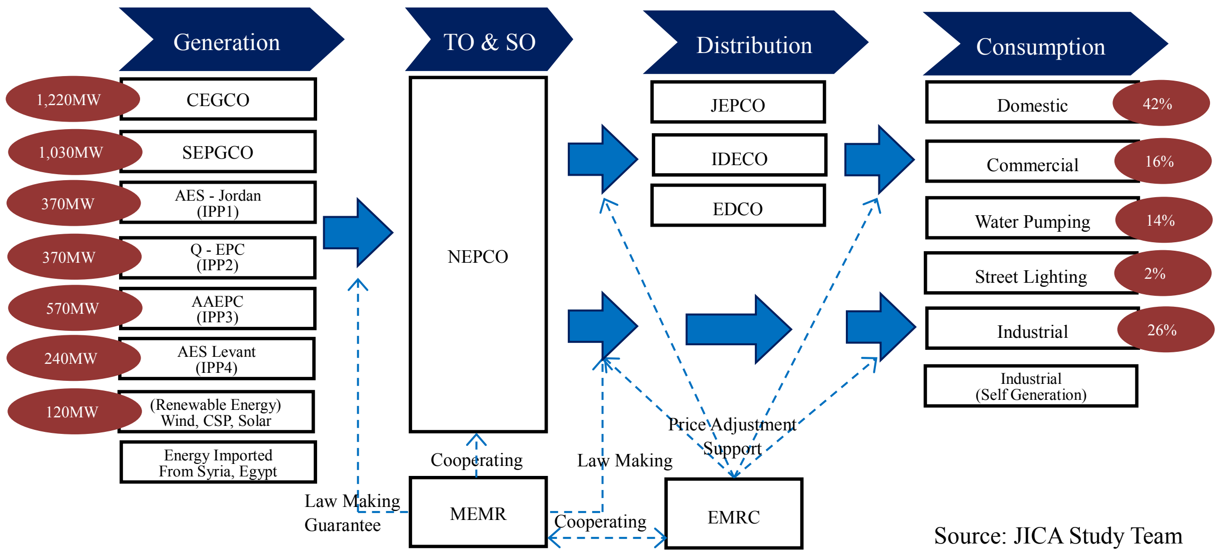
According to “Master Strategy of Energy Sector”, Jordan has a target to install renewable energy which would account for 15% of electricity production by 2025. However, output of renewable energy fluctuates depending on the weather condition and it entails risk to cause load shedding due to a decrease of system frequency.

It is important to estimate acceptable capacity of renewable energy taking system condition into consideration.

Chapter 3　Outline of Electricity Sector

3.1　Outline of Electricity Sector

System reform in electricity sector in Jordan started in 1996. Power generation, transmission and distribution sectors were privatized in 1999. National Electricity Power Company (NEPCO) is operated under the government. NEPCO manages the transmission sector as a single buyer. Ministry of Energy and Mineral Resources (MEMR) has the responsibility in developing long term strategy etc. Energy & Mineral Regulatory Commission (EMRC) are responsible for electricity law, electricity tariff, issue of business license and general regulations of generation, transmission and distribution/retail sales sectors (see Figure 3.1-1).



Source: JICA Study Team

Figure 3.1-1　Whole of the system in electricity sector in Jordan

3.1.1　Generation Sector

Table 3.1-1 shows main power producers in Jordan. NEPCO purchases electric power generated by all power producers in Jordan.

Table 3.1-1　Main power producers in Jordan

	Company	Capacity	Shareholding	Utility
1	Central Electricity Generation Company (CEGCO)	1,687MW	40%:Jordanian Government 60%:Private Company	ST, CCGT,GT
2	Samra Electricity Power Company (SEPCO)	1,050MW	100%:Jordanian Government	CCGT
3	Amman East Power Company (AES-Jordan, IPP1)	370MW	AES, Mitsui	CCGT
4	Qatrana Electric Power Company (Qatrana, IPP2)	420MW	KEPCO, XNEL	CCGT
5	Amman Asia Electric Power Company (AAEPC, IPP3)	573MW	KEPCO, Mitsubishi, WDFS	Diesel Engine
6	Amman East Power Company (AES Levant, IPP4)	240MW	AES, Mitsui	Diesel Engine

Source: JICA Study Team

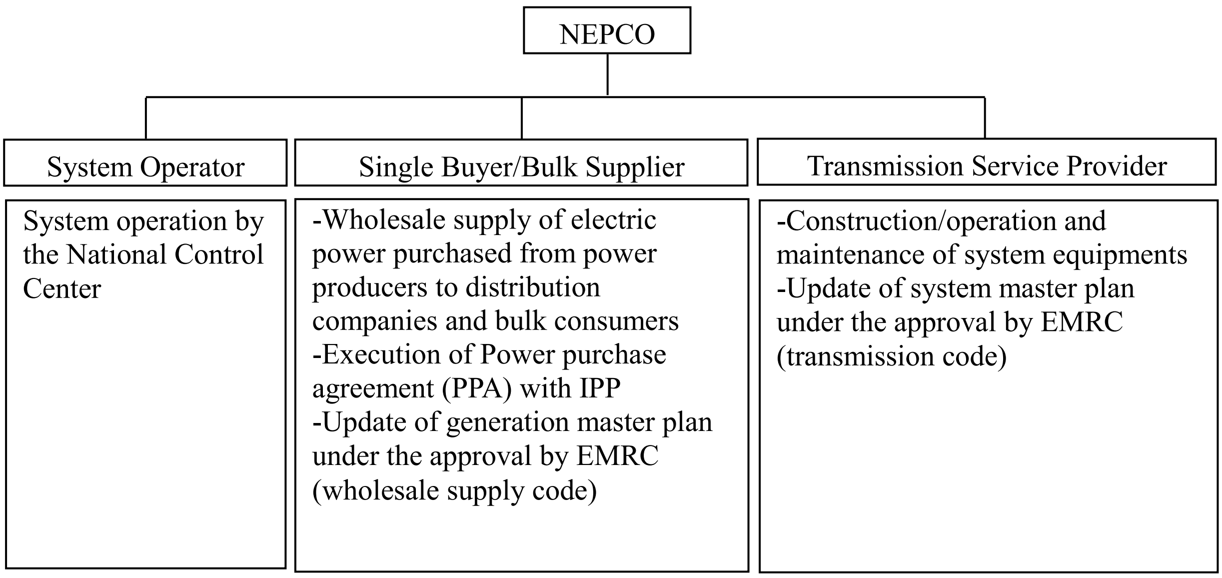
3.1.2 Transmission Sector

Jordan Electricity Authority which had all the responsibility of generation, transmission and distribution sectors was restructured into NEPCO in 1996. Its generation and distribution sectors were separated and became private sequentially and that structure was the same to the current one in1999.

NEPCO has transmission grids and a National Control Center (NCC). The total capacity of its substations is 11,484MVA and the total length of 132kV and 400kV transmission lines is 4,426km.

The tasks of NEPCO are as follows;

- Operation of power system and demand / supply control (System Operator)
- Construction, operation and maintenance of system equipment such as transmission lines and substations (Transmission Network Owner)
- Planning of power system development
- Purchase of electric power from power producers as single buyer and supply of the power to distribution companies and bulk consumers
- Procurement of fuel for thermal power generation
- Import/export of electric power through interconnection with Egypt and Syria



Source: JICA Study Team

Figure 3.1-2 Transmission and distribution sectors in Jordan

3.1.3 Distribution/Retail sales Sector

Generation sector and distribution sector were separated and privatized by electricity system reform in 1996. The following three distribution companies are assigned to the divided areas in Jordan distribution sector.

- Jordan Electric Power Company (JEPCO, a metropolitan area, Jordan central area)
- Irbid District Electricity Company (IDECO, Jordan north area)
- Electricity Distribution Company (EDCO, Jordan south area)

3.2 Law and regulation, institution and procedure for master plan

"Bulk Supply Code" and "Bulk Supply Performance Code" issued by EMRC stipulate laws and regulations related to master plan, EMRC defines "generation master plan", "transmission master plan" and "system master plan" as master plan. "System master plan" is the master plan to which "generation master plan" and "transmission master plan" are combined, and actually"generation master plan" and "transmission master plan" are dealt with as a single plan.

NEPCO formulates "load forecast report", "generation master plan" and "transmission master plan" and these documents should be submitted to EMRC every year. In addition, "power procurement schedule" and "power procurement progress quarterly report" should be also submitted. The submission deadlines for these documents are as follows;

(a) Load forecast report: to be submitted by March 1st every year
(b) Generation master plan and transmission master plan: to be submitted by June 1st every year
(c) Power procurement schedule: to be submitted by August 1st every year
(d) Power procurement progress quarterly reports: to be submitted by February 28th, May 31st, August 31st and November 30th every year.

The delay of submission of these documents is permitted to some extent, and the total number of delay dates for submission of these 4 documents to EMRC should not be more than 80. And EMRC is obligated to approve master plan by July 31st every year.

Chapter 4 Power Demand Forecasts

4.1 General

In general terms, the power demand forecast must be appropriate to the economic and social circumstances of the country in order to ensure the energy and power supply capacity which are positioned as the important factors for reinforcing the economic bases of the country. In addition, when the power demand forecast is calculated, it is important to adopt reasonable calculation conditions and assumptions taking into account the national energy and economic policies.

This chapter is described the long-term power demand forecast in Jordan up to the year 2040.

4.2 Power Demand Forecast Calculated by NEPCO

4.2.1 General

The role of the power demand forecast calculated by NEPCO is to serve as the basis for long-term power system development, financial programme including tariff study and developing activity strategies in Jordan.

NEPCO has periodically conducted review of the power demand forecast every year, and the latest version of power demand forecast report revised in 2013 was made power demand forecast up to 2040.

In the power demand forecast of NEPCO, it is necessary to segment the electricity consumption usage into homogenous groups (sectors) with similar consumption pattern; these sectors are classified into domestic (household), commercial, industry, water pumping, public services and street lighting.

4.2.2 Calculation Conditions of Power Demand Forecast of NEPCO

The power demand forecast of NEPCO consists of three (3) scenarios, which are high, medium and low cases, in consideration of the future vision of power consumption which is assumed based on the present situations in Jordan. In the medium case, moderate economic development assumed by the past data of the economic growth trend is considered, and the said case is to be used as basic data for calculation of the other high and low cases.

Table 4.2-1 Calculation Conditions of NEPCO's Power Demand Forecast

Item	Case 1 (High Case)	Case 2 (Medium Case)	Case 3 （Low Case）
Growth Rate of Population (2004～2012: 2.24%)	2013～2040: 1.7%	2013～2040: 1.6%	2013～2040: 1.5%
Growth Rate of GDP (2004～2012: 5.09%)	Growth Rate of Case 2 + 1%	2013～2026: 3.6% ～5.7% 2027～2038: 6.2% 2039-2040: 6.3%	Growth Rate of Case 2 - 1%
Increase Rate of Energy Consumption of Domestic (2004～2012: 10.13%）	2013～2040: 8.6%	2013～2040: 7.6%	2013～2040: 6.6%
Increase Rate of Energy Consumption of Commercial (2004～2012: 9.41%）	2013～2040: 9.8%	2013～2040: 8.8%	2013～2040: 7.8%
Increase Rate of Energy Consumption of Industry 1)Largy Industry (2004～2012：1.37%） 2)Small and Meddium Industry (2004～2012: 8.13%）	2013～2040: 1) Largy Industry: 2.5% 2) Small and Meddium Industry: 6.9%	2013～2040: 1) Largy Industry: 1.5% 2) Small and Meddium Industry: 5.9%	2013～2040: 1) Largy Industry: 0.5% 2) Small and Meddium Industry: 4.9%
Increase Rate of Energy Consumption of Water Pumping (2004～2012: 5.63%）	2013～2040: 5.6%	2013～2040: 4.6%	2013～2040: 3.6%
Increase Rate of Energy Consumption of Public (2004～2012: 5.2%）	2013～2040：6.6%	2013～2040：5.6%	2013～2040年：4.6%
Increase Rate of Energy Consumption of Street Lighting (2004～2012: 4.59%）	2013～2040: 2.5%	2013～2040: 1.5%	2013～2040: 0.5%
Increase Rate of Energy Consumption of Large Consumer (2000～2012: 2.57%）	2013～2040: 1.98%	2013～2040:1.98%	2013～2040: 1.98%
Transmission Loss (2010: 2.08%）	2013～2040: 2.5%	2013～2040: 2.5%	2013～2040: 2.5%
Distribution Loss (2010: 12.12%）	10% reduction by 2040	10% reduction by 2040	10% reduction by 2040

（Source： Electricity Demand Forecast prepared by NEPCO in 2013）

4.2.3 Result of Calculation of Power Demand Forecast by NEPCO

The results of power demand forecast with three (3) cases calculated by NEPCO are shown in Table 4.2-2, Table 4.2-3 and Table 4.2-4.

Table 4.2-2 Result of NEPCO's Power Demand Forecast (High Case)

[Unit: GWh]

Case 1 (High Case)	2013	2014	2015	2020	2030	2040	Increase Rate (2013-2040) (%)
1. Purchesed Energy	17,581	18,816	20,147	29,196	63,668	139,823	7.98
2. Power Consumption of Distribution Companies	15,350	16,437	17,608	25,572	56,169	124,296	8.05
1) Domestic	5,480	5,905	6,377	9,680	22,816	51,839	8.68
2) Commercial	2,564	2,791	3,045	5,030	14,101	37,398	10.44
3) Industry (Small & Medium)	2,593	2,776	2,971	4,155	8,191	16,944	7.20
4) Industry（Large）	1,136	1,185	1,225	1,390	1,620	1,880	1.88
5) Public	1,220	1,312	1,405	1,946	3,727	7,126	6.76
6) Water Pumping	2,040	2,136	2,240	2,953	5,117	8,313	5.34
7) Street Lighting	318	331	344	419	598	796	3.46
3. Sales Energy to Largy Consumer	985	1,033	1,073	1,234	1,440	1,674	1.98
4. Power Loss (T/L+D/L	1,246	1,346	1,466	2,690	6,059	13,853	10.1

(Source: Electricity Demand Forecast prepared by NEPCO in 2013)

Table 4.2-3 Result of NEPCO's Power Demand Forecast (Medium Case)

[Unit: GWh]

Case 2 (Medium Case)	2013	2014	2015	2020	2030	2040	Increase Rate (2013-2040) (%)
1. Purchesed Energy	17,558	18,720	19,935	27,688	54,967	111,633	7.09
2. Power Consumption of Distribution Companies	15,254	16,278	17,350	24,194	48,472	99,251	7.18
1) Domestic	5,413	5,826	6,267	9,138	19,659	41,501	7.84
2) Commercial	2,550	2,753	2,977	4s,634	11,788	29,599	9.51
3) Industry (Small & Medium)	2,589	2,762	2,941	3,952	7,034	13,004	6.16
4) Industry（Large）	1,136	1,185	1,225	1,390	1,620	1,880	1.88
5) Public	1,213	1,294	1,373	1,802	3,083	5,258	5.58
6) Water Pumping	2,037	2,127	2,224	2,863	4,706	7,247	4.81
7) Street Lighting	318	331	344	415	583	763	3.29
3. Sales Energy to Largy Consumer	985	1,033	1,073	1,234	1,440	1,674	1.98
4. Power Loss (T/L+D/L	1,319	1,409	1,512	2,260	5,055	10,708	8.06

(Source： Electricity Demand Forecast prepared by NEPCO in 2013)

Table 4.2-4 Result of NEPCO's Power Demand Forecast (Low Case)

[Unit: GWh]

Case3 (Low Case)	2013	2014	2015	2020	2030	2040	Increase Rate (2013-2040) (%)
1. Purchesed Energy	17,479	18,530	19,604	26,097	46,862	84,940	6.03
2. Power Consumption of Distribution Companies	15,263	16,193	17,134	22,898	41,451	75,684	6.11
1) Domestic	5,451	5,819	6,206	8,630	16,785	31,868	6.76
2) Commercial	2,535	2,716	2,910	4,267	9.574	21,066	8.16
3) Industry (Small & Medium)	2,584	2,748	2,911	3,757	6,032	9,955	5.12
4) Industry（Large）	1,136	1,185	1,225	1,390	1,620	1,880	1.88
5) Public	1,206	1,276	1,340	1,667	2,548	3,874	4.42
6) Water Pumping	2,034	2,118	2,208	2,776	4,325	6,312	4.28
7) Street Lighting	318	330	343	411	568	730	3.13
3. Sales Energy to Largy Consumer	985	1,033	1,073	1,234	1,440	1,674	1.98
4. Power Loss (T/L+D/L	1,231	1,304	1,397	1,965	3,971	7,582	6.97

(Source: Electricity Demand Forecast prepared by NEPCO in 2013

As shown in the above Table 4.2-3, it is forecasted in Case 2 (medium case) that incremental purchased energy from the generating company in the period of 2013-2040 is 94,075 GWh (=111,633-17,558 GWh) and its annual average growth rate is 7.09%.

4.2.4 Result of Calculation of NEPCO's Peak Demand Forecast

The peak demand forecast by NEPCO is calculated based on the following formula using peak load, consumed energy, load factor and coincident factors of each sector.

$$PL_i = \frac{E_i}{8.76 * LF_i}$$

$$CL_{m,i} = PL_i * CF_{m,i}$$

$$CL_{e,i} = PL_i * CF_{e,i}$$

Where:

PLi: Sector peak load [MW]

Ei: Sector consumed energy [GWh]

LFi: Sector load factor

CLm,i: Sector coincident load at morning time [MW]

CLe,i: Sector coincident load at evening time [MW]

CFm,i: Sector coincident factor at morning time

CFe,i: Sector coincident factor at evening time

Table 4.2-5 Load Factors and Coincident Factors for All Sectors

Sector	LF	CF,m	CF,e
Domestic	0.51	0.53	0.83
Commercial	0.49	0.83	0.62
Industry	0.64	0.83	0.47
Service	0.37	0.84	0.26
Water Pumping	0.73	1.00	1.00
Street Lighting	0.50	0.00	1.00

Source: Electricity Demand Forecast prepared by NEPCO in 2013

The peak demand forecast calculated by the above formula is shown in the table below.

Table 4.2-6 Peak Demand Forecast by NEPCO

	2013	2014	2015	2020	2030	2040
1. Case 1 (High Case)						
- Peak Demand [MW]	2,723	2,994	3,199	4,537	9,628	20,606
- Load Factor [%]	0.72	0.70	0.70	0.72	0.74	0.76
2. Case 2 (Medium Case)						
- Peak Demand [MW]	2,707	2,965	3,149	4,283	8,285	16,395
- Load Factor [%]	0.73	0.71	0.71	0.72	0.74	0.76
3. Case 3 (Low Case)						
- Peak Demand (MW)	2,705	2,946	3,107	4,405	7,071	12,462
- Load Factor [%]	0.72	0.70	0.71	0.72	0.74	0.77

Source: Electricity Demand Forecast prepared by NEPCO in 2013

As shown in the table above, it is forecasted in Case 1 (medium case) that the average annual growth rate of peak demand in the period of 2013-2040 is 6.9% and the peak demand in 2040 is expected to be 16,395 MW which is equivalent to 6.1 times the past peak demand record 2,707 MW in 2013.

4.3 Power Demand Forecast by JICA Study Team

The methodology of power demand forecast is broadly classified into macro and micro methods.

- Macro method, which makes an analysis from the viewpoint of the general situation. The power demand and peak power are forecasted by finding and using a certain trend or correlativity to the whole power demand in the country.
- Micro method, whereby the aggregate is derived on the basis of the estimation after classifying demands into each type of demand. A detailed analysis of demand is made by categorizing it into constituents, and the total power demand is derived from estimations made for each constituent. The most common classification employs a method by dividing the power demand into several tariff type groups: however they are usually simplified by mixing similar consumers.

In this master plan, the both macro and micro methods are calculated up to the year 2040 by using the population growth rate, economic growth rate and transition of economic and industry trends for macro method, and using the accumulated incremental power demand for each sector based on analyzed past data and development plan of each sector for micro method.

4.3.1 Macro Method of Power Demand Forecast

(1) Calculation Procedure

i) The data of GDP, population and power consumption of the past 10 years in the period of 2005- 2014. GDP and population data are quoted from ones published by Department of Statistics of Jordan described in the NEPCO's report of power demand forecast revised in 2015, and the power consumption data is obtained from three (3) distribution companies (JEPCO, IDECO and EDCO).

GDP and GDP/capita with its growth rate in the period of 2005-2014 are shown in the table below.

Table 4.3-1 GDP and GDP/Capita (2005-2014)

Year	GDP			GDP per Capita			
	GDP [JD]	Growth Rate of GDP [%]		Population	GDP/Capita [JD]	Growth Rate of GDP/capita [%]	
2005	6,404,000,000	7.58	4.35	5,473,000	1,170.11	5.16	2.07
2006	6,920,000,000	8.06		5,600,000	1,235.71	5.61	
2007	7,420,000,000	7.23		5,723,000	1,296.52	4.92	
2008	7,914,000,000	6.66		5,850,000	1,352.82	4.34	
2009	8,083,000,000	2.14		5,980,000	1,351.67	-0.08	
2010	8,358,000,000	3.40		6,113,000	1,367.25	1.15	
2011	8,635,000,000	3.31		6,249,000	1,381.82	1.07	
2012	8,855,000,000	2.55		6,388,000	1,386.19	0.32	
2013	9,099,000,000	2.76		6,530,000	1,393.42	0.52	
2014	9,393,000,000	3.23		6,675,000	1,407.19	0.99	

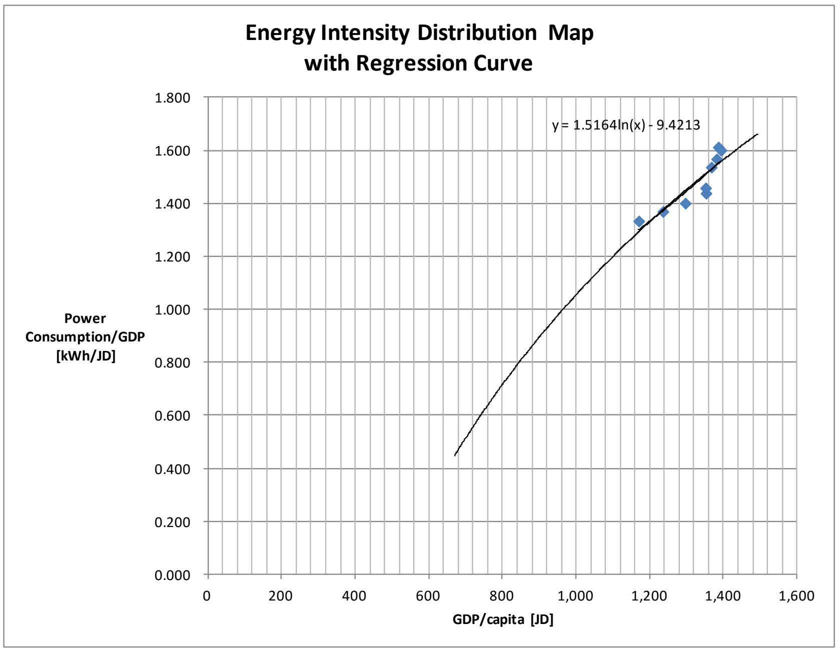
Source: Department of Statistics

ii) By using the collected data in the above i), an energy intensity distribution map which consists of GDP/capita [JD] and power consumption/GDP [GWh/JD] is prepared, and then, the regression curve with logarithmic approximation is formulated based on the said energy intensity distribution map.

Table 4.3-2 GDP/Capita and Power Consumption/GDP (2005-2014)

Year	GDP/Capita [JD]	Power Consumption/GDP [kWh/JD]		
		Power Consumption [GWh]	GDP [JD]	Power Consumption/GDP [kWh/JD]
2005	1,170.11	8,538	6,404,000,000	1.333
2006	1,235.71	9,475	6,920,000,000	1.369
2007	1,296.52	10,393	7,420,000,000	1.401
2008	1,352.82	11,381	7,914,000,000	1.438
2009	1,351.67	11,786	8,083,000,000	1.458
2010	1,367.25	12,843	8,358,000,000	1.537
2011	1,381.82	13,535	8,635,000,000	1.567
2012	1,386.19	14,277	8,855,000,000	1.612
2013	1,393.42	14,564	9,099,000,000	1.601
2014	1,407.19	15,418	9,393,000,000	1.641

Source: Department of Statistics, JEPCO, IDECO and EDCO



Source: JICA Study Team

Figure 4.3-1 Energy Intensity Distribution Map and Log Approximation

iii) The annual average growth rate of each indicator of GDP, population and power consumption up to 2040 is assumed in each case of high, medium and low. The average annual growth rate of GDP and GDP/capita is set based on the historical data as below:

- Case 1 (High Case): Annual average increase rate in the period of 2005-2014 (GDP: 4.35%、GDP/capita: 2.07%)
- Case 2 (Medium Case): Annual average increase rate in the period of 2009-2014 (GDP: 3.05%、GDP/capita: 0.81%)
- Case 3 (Low Case): Case 2 minus 0.5% (GDP: 2.55%、GDP/capita: 0.31%)

Table 4.3-3 Average Increase Rate of GDP and GDP/Capita per Each Case

<table>
<tr><th rowspan="2">Year</th><th colspan="5">GDP</th><th colspan="5">GDP/Capita</th></tr>
<tr><th>[JD]</th><th>Growth Rate [%]</th><th>High</th><th>Mid.</th><th>Low</th><th>[JD]</th><th>Growth Rate [%]</th><th>High</th><th>Mid.</th><th>Low</th></tr>
<tr><td>2005</td><td>6,404,000,000</td><td>7.58</td><td rowspan="10">4.35</td><td rowspan="4">/</td><td rowspan="4">/</td><td>1,170.11</td><td>5.16</td><td rowspan="10">2.07</td><td rowspan="4">/</td><td rowspan="4">/</td></tr>
<tr><td>2006</td><td>6,920,000,000</td><td>8.06</td><td>1,235.71</td><td>5.61</td></tr>
<tr><td>2007</td><td>7,420,000,000</td><td>7.23</td><td>1,296.52</td><td>4.92</td></tr>
<tr><td>2008</td><td>7,914,000,000</td><td>6.66</td><td>1,352.82</td><td>4.34</td></tr>
<tr><td>2009</td><td>8,083,000,000</td><td>2.14</td><td rowspan="6">3.05</td><td rowspan="6">2.55</td><td>1,351.67</td><td>-0.08</td><td rowspan="6">0.81</td><td rowspan="6">0.31</td></tr>
<tr><td>2010</td><td>8,358,000,000</td><td>3.40</td><td>1,367.25</td><td>1.15</td></tr>
<tr><td>2011</td><td>8,635,000,000</td><td>3.31</td><td>1,381.82</td><td>1.07</td></tr>
<tr><td>2012</td><td>8,855,000,000</td><td>2.55</td><td>1,386.19</td><td>0.32</td></tr>
<tr><td>2013</td><td>9,099,000,000</td><td>2.76</td><td>1,393.42</td><td>0.52</td></tr>
<tr><td>2014</td><td>9,393,000,000</td><td>3.23</td><td>1,407.19</td><td>0.99</td></tr>
</table>

Source: Department of Statistics, JICA Study Team

As shown in the above table, the annual average growth rate of GDP in the period of 2005-2008 was recorded 7.31%. However, by reason of the national economy experienced a marked slowdown after 2009 affected by the global financial crisis and its negative repercussion on regional and global economic growth, the annual average growth rate of GDP in the period of 2009-2014 was recorded 3.05%.

The expected annual average growth rate after 2015 is determined that 3.05% is a realistic numerical number to adopt the calculation of power demand forecast in Case 2 (Medium Case).

iv) The power consumption [GWh] until 2040 is calculated based on the above item ii) and iii).

The result of macro method power demand forecast calculated by JICA Study Team in accordance with the above procedures is shown in the table below.

Table 4.3-4 Macro Method Power Demand Forecast (Power Consumption of Distribution Companies)

		2015	2020	2025	2030	2035	2040
Power Consumption							
Case 1: High Case	(GWh)	15,709	21,319	28,706	38,397	51,072	67,597
Case 2: Medium Case	(GWh)	15,331	18,502	22,298	26,839	32,266	38,748
Case 3: Low Case	(GWh)	15,184	17,475	20,109	23,134	26,610	30,601

Source: JICA Study Team

The calculation results (high, medium and low cases) of Macro Method Power Demand Forecast energy at 5years interval in the period of 2015-2040, which are sum of the power consumption of the distribution companies, sales energy to large consumers, power selling to overseas and powr losses (T/L+D/L), are shown in Table 4.3-5, Table 4.3-6 and Table 4.3-7 respectively.

The calculation results every year up to 2040 are shown in Appendix -1.

Table 4.3-5 Macro Method Power Demand Forecast (High Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	18,390	24,783	33,186	44,239	58,574	77,194	5.91
1) Power Consumptin of Distribution Companies	15,709	21,319	28,706	38,397	51,072	67,597	6.01
2) Sales Energy to Large Consumer	1,209	1,372	1,527	1,681	1,769	1,884	1.79
3) Power Selling to Overseas	39	39	39	39	39	39	1.00
4) T/L Loss	341	451	595	801	1,011	1,285	5.45
5) D/L Loss	1092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2) to 5) are quoted from ones of NEPCO's forecasted values

Source: JICA Study Team

Table 4.3-6 Macro Method Power Demand Forecast (Medium Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	17,898	21,837	26,635	32,524	39,603	48,170	4.04
1) Power Consumptin of Distribution Companies	15,331	18,502	22,298	26,839	32,266	38,748	3.78
2) Sales Energy to Large Consumer	1,099	1,247	1,388	1,528	1,608	1,713	1.79
3) Power Selling to Overseas	35	35	35	35	35	35	1.00
4) T/L Loss	341	451	595	801	1,011	1,285	5.45
5) D/L Loss	1,092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2) to 5) are quoted from ones of NEPCO's forecasted values

Source: JICA Study Team

Table 4.3-7 Macro Method Power Demand Forecast (Low Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	17,638	20,682	24,304	28,663	33,783	39,849	3.31
1) Power Consumptin of Distribution Companies	15,184	17,475	20,109	23,134	26,610	30,601	2.84
2) Sales Energy to Large Consumer	989	1,122	1,249	1,375	1,447	1,542	1.79
3) Power Selling to Overseas	32	32	32	32	32	32	1.00
4) T/L Loss	341	451	595	801	1,011	1,285	5.45
5) D/L Loss	1,092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2) to 5) are quoted from ones of NEPCO's forecasted values

Source: JICA Study Team

4.3.2 Micro Method of Power Demand Forecast

(1) Calculation Procedure

The micro method power demand forecast is accumulated the future power demand which is forecasted by each power supply category divided into 6 sectors which are domestic, commercial, industry, public services, water pumping and street lighting up to 2040.

i) Domestic Sector

The domestic load refers to power demand consumed directly in households. It is classified into flat rate lighting and meter rate lighting, which is further divided into a lighting demand and equipment demand.

a) Forecast of Population Increase

According to the data published by Department of Statistics of Jordan in 2013, the number of inhabitants actually living in Jordan classified by governorate in the period of 1995-2012 is available as shown in the table below.

Table 4.3-8 Population of Jordan

		1995	2000	2005	2009	2010	2011	2012	Growth Rate
Total	(x 1000)	4,264	4,857	5,230	5,980	6,113	6,249	6,388	2.41%
Amman	(x 1000)	1,624	1,885	2,029	2,316	2,367	2,420	2,473	2.50%
Balqa	(x 1000)	284	325	350	401	410	419	428	2.31%
Zarqa	(x 1000)	659	724	779	891	911	934	952	2.19%
Madaba	(x 1000)	110	121	131	150	153	156	160	2.23%
Irbid	(x 1000)	774	865	931	1,064	1,088	1,112	1,137	2.29%
Mafraq	(x 1000)	127	228	246	281	287	294	300	5.19%
Jarash	(x 1000)	127	146	157	179	183	188	192	2.46%
Ajlun	(x 1000)	97	112	120	138	141	144	147	2.48%
Karak	(x 1000)	175	189	204	233	238	244	249	2.10%
Tafiela	(x 1000)	65	68	73	84	86	88	89	1.87%
Ma'an	(x 1000)	82	92	99	114	116	119	121	2.32%
Aqaba	(x 1000)	82	102	110	130	133	136	139	3.15%

Source: Department of Statistics

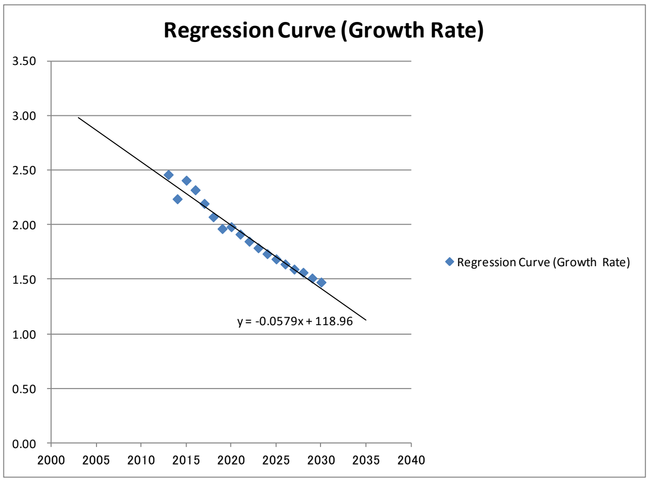
Jordan national population in the period of 1995 to 2012 increased 2.41% at annual average rate. In this master plan, the population increase rate up to 2040 is assumed by regression curve and logarithmic approximation indicated in Figure 4.3-2 which is made based on the historical data of population published by Department of Statistics of Jordan.

It should be noted that, since the year of 2011, although a large number of Syrian refugees have been flowing into Jordan, it cannot be confirmed any impact of Syrian refugees on the numerical values in power consumption, especially for domestic sector, from the past record of the power demand after 2011.

In addition, although JICA Study Team has confirmed that USAID published the official report titled "The Fiscal Impact of the Syrian Refugee Crisis on Jordan" in 2014 which was prepared based on the result of study conducted for the purpose of estimating the fiscal effects of the Syrian refugees on the Jordan budget, the Government of Jordan does not have official data of the number of Syrian refugees living in the country at the present moment and future.

Therefore, in the same way as NEPCO's power demand forecast, JICA Study Team decided not to take into account the impact of Syria refugees on the power demand forecast up to 2040 in this master plan.

Figure 4.3-2 Regression Curve and Log Approximation related to Population in Jordan



Source: JICA Study Team

Table 4.3-9 Population Forecast up to 2040

		2015	2020	2025	2030	2035	2040
1. Population	(x1,000)	6,822	7,569	8,267	8,932	9,556	10,134
2. Increase Rate	(%)	(2014-15) 2.20	(2015-20) 2.10	(2020-25) 1.78	(2025-30) 1.56	(2030-35) 1.36	(2035-40) 1.18

Source: JICA Study Team

b) Number of Households in Domestic

According to the data of Department of Statistics, the number of population of Jordan in 2010 was 6,113,000, while the number of households was 1,134,177. From those data, it can be calculated that the average number of people per household is 5.4. In this master plan, the average number of people per household across the country is assumed as the same level, which is to say 5.4 people per household until 2040.

The geographical coverage by the distribution network or, in other words, electrification ratio in the country is almost entirely reached at 100% in the both of urban and rural area in the country.

c) Unit Consumption per Households

The power consumption per household is forecasted based on the estimated penetration rate of electrical appliances by each household. Table 4.3-10 shows the penetration rate of each household appliance. In the table, the data of penetration rate in the period of 2008 to 2011 is actual value obtained from Department of Statistics and the increase penetration rate after 2012 is assumed by United Nations Development Programme (UNDP) and JICA Study Team. (Air conditioning: 1.47%/year, Washing machine:0.0057%/year, Refrigerator:0.0085%/year, Freezer:2.14%/year, TV:0.1%/year, Vacuum cleaner:6.1%/year, Micro-wave:27.7%/year, Computer:12.2%/year)

Table 4.3-10 Penetration Rate of Household Appliances

[Unit: %]

Item	2008	2009	2010	2011	2012	2020	2030	2040
Air–conditioner	7.8	7.9	13.5	14.9	21.0	23.6	27.3	31.6
Washing Machine	97.3	97.6	97.9	95.1	98.0	98.0	98.1	98.2
Refrigerator	97.2	97.6	98.1	95.3	98.2	98.2	98.3	98.4
Freezer	9.2	9.9	11.8	12.1	14.0	16.6	20.5	25.3
TV	98.7	No data	98.9	98.9	98.9	98.9	98.9	98.9
Vacumm Cleaner	56.3	No data	63.4	64.0	64.7	70.0	77.4	85.5
Micro-wave	23.8	No data	38.8	39.2	39.6	42.9	47.3	52.3
Computer	36.3	No data	45.7	46.2	46.6	50.5	55.8	61.6

Source: Department of Statistics, JICA Study Team

Annual power consumption of household appliances is also estimated as shown in the table below.

Table 4.3-11 Power Consumption of Household Appliances

	kW	Hour/Date	kWh/Year
Air–conditioner	1.8	12.0	3,240
Washing Machine	1.8	1.5	986
Refrigerator	0.2	12.0	876
Freezer	0.2	12.0	876
TV	0.2	3.0	329
Vacumm Cleaner	1.2	0.5	219
Micro-wave	1.5	0.5	274
Computer	0.12	3.0	219
Lighting	0.42	6.0	986
Total	-	-	5,086

Note: Air-conditioner is assumed to be used for 5 months (June – October)

Source: JICA Study Team

d) Power Demand Forecast of Domestic Sector

The power consumption figures of domestic sector are calculated by the number of households multiplied by the unit consumption by household.

The power demand forecast of domestic sector is shown in the next below.

Table 4.3-12 Power Demand Forecast of Domestic Sector

		2015	2020	2025	2 030	2035	2040
1. Power Consumption	(GWh)	5,518	6,248	6,974	7,702	8,388	9,017
1) Air–conditioner		904	1,079	1,268	1,473	1,686	1,903
2) Washing Machine		1,228	1,363	1,490	1,610	1,714	1,798
3) Refrigerator		1,093	1,214	1,327	1,434	1,527	1,602
4) Freezer		166	205	249	299	354	413
5) TV		413	458	501	541	576	604
6) Vacumm Cleaner		186	216	249	282	316	348
7) Micro-wave		142	116	190	216	242	266
8) Computer		134	156	179	203	227	251
9) Lighting		1,253	1,390	1,520	1.642	1,747	1,832
2. Incread Rate	(%)	-	(2015-20) 2.52	(2020-25) 2.22	(2025-30) 2.01	(2030-35) 1.72	(2035-40) 1.46

Source: JICA Study Team

ii) Commercial Sector

a) Relevance of GDP and power consumption

Commercial sector plays an important role in the economic development of Jordan, also a percentage of GDP of the entire country accounted for 52.8% in 2014.

The electricity consumption is closely related to the economic activities, especially for industrial and commercial sectors. In power demand forecast of the industrial and commercial sectors, the growth of GDP is considered to be an important parameter in estimating future power consumption.

The elasticity, relation factor between growth rates of power consumption and GDP in the respective sector, is obtained from the historical trends of power consumption and GDP as presented by the following formula:

$$\text{Elasticity} = \frac{\text{Average Growth Rate of Energy Demand (\%)}}{\text{Average Growth Rate of GDP (\%)}}$$

The relevance of the growth rates of power consumption and GDP for commercial sector is calculated from the historical data as shown in the table below.

Table 4.3-13 Relevance between Power Consumption and GDP Growth Rate (Commercial Sector)

	Average Grow Rate (2005～2014)	Coefficient to GDP Growth Rate
1. GDP Growth Rate (%)		
(a) Overall	4.35	-
(b) Commercial	5.00	-
2. Power Consumption Increase Rate (%)		
(a) Overall	6.79	1.56
(b) Commercial	6.77	1.35

Source: JICA Study Team

The elasticity of commercial sector is calculated as shown in the table below.

Table 4.3-14 Elasticity of Commercial Sector

	Elasticity
Commercial	1.35

Source: JICA Study Team

The growth rate of GDP in commercial sector up to 2040 is utilized the figures in the following table which are forecasted by MoP of Jordan based on the social and economic development policies of the Government of Jordan.

Table 4.3-15 Forecasted Growth Rate of GDP (Commercial Sector)

[Unit: %]

	2015	2016-2017	2018	2019-2020	2021-2032	2033	2034-2040
GDP (Commercial)	5.7	5.1	5.2	5.7	6.1	5.9	6.0

Source: Electricity Demand Forecast prepared by NEPCO in 2015

The growth rate of power consumption of the commercial sector is calculated as shown in the table below.

Table 4.3-16 Forecasted Increase Rate of Power Consumption (Commercial Sector)

[Unit: %]

	2015	2016-2017	2018	2019-2020	2021-2032	2033	2034-2040
Commercial	7.70	6.89	7.02	7.70	8.24	7.97	8.10

The power demand forecast of commercial sector is calculated as shown in the table below.

Table 4.3-17 Power Demand Forecast of Commercial Sector

		2015	2020	2025	2030	2035	2040
1. Power Consumption	(GWh)	2,466	3,497	5,195	7,716	11,404	16,834
2. Increase Rate	(%)	(2014-15) 7.69	(2015-20) 7.24	(2020-25) 8.24	(2025-30) 8.23	(2030-35) 8.13	(2035-40) 8.10

Source: JICA Study Team

iii) Industry Sector

The power consumption of industrial sector, in the same manner as commercial sector is closely related to the economic activities. In forecasting the power demand of industrial sector, the growth rate of GDP is considered to be an important parameter in estimating future power consumption.

The relevance of the growth rates of power consumption and GDP for industry sector is calculated from the historical data as shown in the table below.

Table 4.3-18 Relevance between Power Consumption and GDP Growth Rate (Industry Sector)

	Average Growth Rate (2005～2014)	Coefficient to GDP Growth Rate
1. GDP Growth Rate (%)		
(a) Overall	4.35	-
(b) Commercial	4.18	-
2. Power Consumption Increase Rate (%)		
(a) Overall	6.79	1.56
(b) Commercial	5.56	1.33

Source: JICA Study Team

The elasticity of Industry sector is calculated as shown in the table below.

Table 4.3-19 Elasticity of Industry Sector

	Elasticity
Industry	1.33

Source: JICA Study Team

The growth rate of GDP in industry sector up to 2040 is utilized the figures in the following table which are forecasted by MoP of Jordan based on the social and economic development policies of the Government of Jordan.

Table 4.3-20 Forecasted Growth Rate of GDP (Industry Sector)

[Unit: %]

	2015	2016	2017	2018	2019	2020-2040
GDP (Industry)	4.5	4.8	4.5	4.8	4.9	4.5

Source: Electricity Demand Forecast prepared by NEPCO in 2013

The growth rate of power consumption of industry sector is calculated as shown in the table below.

Table 4.3-21 Forecasted Increase Rate of Power Consumption (Industry Sector)

[Unit: %]

	2015	2016	2017	2018	2019	2020-2040
Industry	5.99	6.38	5.99	6.38	6.52	5.99

Source: JICA Study Team

The power demand forecast of industry sector is calculated as shown in the table below.

Table 4.3-22 Power Demand Forecast of Industry Sector

		2015	2020	2025	2030	2035	2040
1. Power Consumption	(GWh)	4,109	5,564	7,441	9,950	13,307	17,795
2. Increase Rate	(%)	(2013-14) 5.98	(2015-20) 6.25	(2020-25) 5.99	(2025-30) 5.98	(2030-35) 5.59	(2035-40) 5.98

Source: JICA Study Team

iv) Water Pumping Sector

The major challenges, which the water pumping business in water sector in Jordan is currently facing, are pointed to mainly 1) development of water resources and management of water demand, 2) management of water supply services and facilities, and 3) financial problems.

The substantial factors of financial problems on the above are considered as high unwaged water rate, high energy cost, high water resource development cost, and increasing deficit financial etc.

Of the above-mentioned factors causing financial problems, the several factors are considered as the reasons of high energy cost, 1) increase in water consumption, 2) increase in the water head due to lowering groundwater level, 3) decrease in efficiency of the existing pumps caused by deterioration or insufficient maintenance.

In order to suppress the increase of power consumption in the water sector, Water Authority of Jordan (WAJ) has planned to carry out Energy Efficiency Projects (EEP) with the support of Germany (loan of 80% of the total project budget is covered by KFW and the remaining 20% is funded by WAJ).

The scope of the project is included 19 places of pump stations and 105 sites of well, and it targets to reduce by 15% the power consumption in 2013 until the year of 2025 by implementation of the project.

The reduction target value of the power consumption implemented by EEP is shown in the table below.

Table 4.3-23 Target of Energy Consumption Reduction by EEP

–	Baseline 2013	2017		2021		2025	
		Base Case	Optimistic	Base Case	Optimistic	Base Case	Optimistic
Energy Consumption (Target)	0%	5.25%	7.27%	10.50%	13.60%	15%	20%

Source: Water Authority of Jordan

The expected energy saving in water sector up to 2040 is assumed as the table below which is forecasted by a regression curve and logarithmic approximation formula based on the target reduction rate of energy saving by implementation of EEP as shown in Table 4.3-24.

Table 4.3-24 Expected Energy Saving for Water Sector by 2040

Year	2017	2021	2025	2030	2035	2040
Energy Saving [%] $y = 1.2188x - 2452.8$	5.25	10.50	15.00	21.36	27.46	33.55

Source: JICA Study Team

The power demand forecast of Water Pumping sector is shown in the table below.

Table 4.3-25 Power Demand Forecast of Water Pumping Sector

		2015	2020	2025	2030	2035	2040
1. Power Consumption	(GWh)	2,485	3,051	3,647	4,231	4,805	5,322
2. Increase Rate	(%)	(2014-15) 8.80	(2015-20) 4.19	(2020-25) 3.63	(2025-30) 3.02	(2030-35) 2.58	(2035-40) 2.06

Source: JICA Study Team

v) Public Services Sector

The power consumption of public services sector such as government building, state-run television station, international airport, etc is assumed to grow in proportion to the growth of population.

The population growth trend up to 2040 is assumed by the regression curve and logarithmic approximation formula related to the population growth rate.

The power demand forecast of public services sector is shown in the table below.

Table 4.3-26 Power Demand Forecast of Public Services Sector

		2015	2020	2025	2030	2035	2040
1. Population	(x1,000)	6,822	7,569	8,267	8,932	9,556	10,134
2. Increase Rat（Population）	(%)	(2014-15) 2.20	(2015-20) 2.10	(2020-25) 1.78	(2025-30) 1.56	(2030-35) 1.36	(2035-40) 1.18
3. Power Consumption	(GWh)	1,192	1,322	1,444	1,560	1,669	1,770
4. Increase Rate (Power Consumption)	(%)	(2014-15) 2.20	(2015-20) 2.10	(2020-25) 1.78	(2025-30) 1.56	(2030-35) 1.36	(2035-40) 1.18

Source: JICA Study Team

vi) Street Lighting Sector

The power consumption of street lighting sector is linked with the number of domestic consumers. The electricity consumption of street lighting sector is assumed to grow in proportion to the growth of the number of domestic consumers.

In Jordan as of the year 2011, the total length of the existing 33kV and 11kV distribution lines in 2011 was 16,464km. In accordance with JEPCO's plan which will be extended 33kV and 11kV distribution lines 90km annually, the said plan is taken into account when the future distribution line length is assumed for calculation of power demand forecast of street lighting sector. In addition, the extension plans of distribution lines by other distribution companies (IDECO and EDCO) shall be considered in the next step.

The power demand forecast of street lighting sector is shown in the table below.

Table 4.3-27 Power Demand Forecast of Street Lighting Sector

		2015	2020	2025	2030	2035	2040
1. Distance of Distribution Line (D/L)	(km)	16,824	17,274	17,724	18,174	18,624	19,074
2. Increase Rate（D/L）	(%)	(2014-15) 0.53	(2015-20) 0.53	(2020-25) 0.52	(2025-30) 0.50	(2030-35) 0.49	(2035-40) 0.48
3. Power Consumption	(GWh)	318	326	335	343	352	360
4. Increase Rate (Power Consumption)	(%)	(2014-15) 0.63	(2015-20) 0.50	(2020-25) 0.55	(2025-30) 0.47	(2030-35) 0.52	(2035-40) 0.45

Source: JICA Study Team

(2) Result of Micro Method Power Demand Forecast

The calculation results (high, medium and low cases) of Micro Power Demand Forecast at 5 years interval in the period of 2015-2040 are shown in Table 4.3-28, Table 4.3-29 and Table 4.3-30 respectively.

The calculation results every year up to 2040 are shown in Appendix-2.

Table 4.3-28 Micro Method Power Demand Forecast (High Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	19,802	25,271	32,610	42,621	56,330	75,573	5.50
1. Sales Energy	17,122	19,844	16,126	25,421	39,696	69,689	5.78
1) Domestic	6,070	6,873	7,671	8,472	9,227	9,919	1.98
2) Commercial	2,497	3,770	5,957	9,415	14,805	23,254	9.34
3) Industry	4,161	5,996	8,534	12,146	17,288	24,606	7.37
4) Public	1,311	1,454	1,588	1,716	1,836	1,947	1.59
5) Water Pumping	2,734	3,356	4,012	4,654	5,286	5,854	3.09
6) Street Lighting	349	359	368	378	387	396	0.51
2. Sales Energy to Large Consumer	1,209	1,372	1,527	1,681	1,769	1,884	1.79
3.Selling to Overseas	39	39	39	39	39	39	0.00
4. T/L Loss	341	451	595	801	1,011	1,285	5.45
5. D/L Loss	1,092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2 to 5 are quoted from ones of NEPCO’s forecasted values

Source: JICA Study Team

Table 4.3-29 Micro Method Power Demand Forecast of Street Lighting Sector (Medium Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	18,655	23,343	29,372	37,187	47,262	60,520	4.82
1. Sales Energy	16,088	20,008	25,036	31,502	39,925	51,098	4.73
1) Domestic	5,518	6,248	6,974	7,702	8,388	9,017	1.98
2) Commercial	2,466	3,497	5,195	7,716	11,404	16,834	7.99
3) Industry	4,109	5,564	7,441	9,950	13,307	17,795	6.04
4) Public	1,192	1,322	1,444	1,560	1,669	1,770	1.59
5) Water Pumping	2,485	3,051	3,647	4,231	4,805	5,322	3.09
6) Street Lighting	318	326	335	343	352	360	0.51
2. Sales Energy to Large Consumer	1,099	1,247	1,388	1,528	1,608	1,713	1.79
3.Selling to Overseas	35	35	35	35	35	35	0.00
4. T/L Loss	341	451	595	801	1,011	1,285	5.45
5. D/L Loss	1,092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2 to 5 are quoted from ones of NEPCO's forecasted values.

Source: JICA Study Team

Table 4.3-30 Micro Method Power Demand Forecast (Low Case)

[Unit: GWh]

Item	2015	2020	2025	2030	2035	2040	Increase Rate (2015-40) (%)
Purchesed Energy	17,508	21,459	26,353	32,420	39,830	49,023	4.20
1. Sales Energy	15,054	18,253	22,159	26,891	32,659	39,775	3.96
1) Domestic	4,967	5,623	6,276	6,931	7,550	8115	1.98
2) Commercial	2,435	3,241	4,522	6,308	8,756	12,137	6.64
3) Industry	4,057	5,159	6,477	8,131	10,209	12,816	4.71
4) Public	1,072	1,190	1,300	1,404	1,502	1,593	1.60
5) Water Pumping	2,237	2,746	3,283	3,808	4,325	4,790	3.09
6) Street Lighting	286	294	301	309	317	324	0.51
2. Sales Energy to Large Consumer	989	1,122	1,249	1,375	1,447	1,542	1.79
3.Selling to Overseas	32	32	32	32	32	32	0.00
4. T/L Loss	341	451	595	801	1,011	1,285	5.45
5. D/L Loss	1,092	1,602	2,319	3,321	4,683	6,389	7.32

Note) The above items 2 to 5 are quoted from ones of NEPCO's forecasted values

Source: JICA Study Team

4.3.3 Peak Demand Forecast

The historical data of the peak demand, annual power consumption and load factor in the period of 2005-2014 is shown in Table 4.3-31.

The peak demand is meant the maximum value of the power demand during a given period. In general, the average power consumption per hour is employed. The annual peak demand is obtained from the power demand and the annual load factor.

As shown in the table below, the load factor was changed the narrow range year by year. Therefore, the load factor of the annual average value in the period of 2005-2014 (0.69) is adopted to be used for calculation of the peak demand forecast.

Table 4.3-31 Historical Data of Peak Demand

	2005	2007	2010	2012	2013	2014
- Annual Purchased Energy (GWh)	9,742	12,232	14,617	16,469	16,720	17,692
- Peak Demand (MW)	1,642	2,045	2,544	2,770	2,650	2,845
- Load Factor (%)	0.68	0.69	0.66	0.68	0.72	0.71

Source: JICA Study Team

For conducting the peak load forecast, the load factor of Jordan is assumed to remain unchanged at around 0.69 through the study period up to the year 2040 as no definite causes to change load factor can be identified.

The peak demand forecast with condition of "Load Factor=0.69" at 5 years interval in the period of 2015-2040 are shown in Table 4.3-32.

The calculation results every year up to 2040 are shown in Appendix-3.

Table 4.3-32 Peak Demand Forecast (LF=0.69)

	2015	2020	2025	2030	2035	2040
High Case						
- Annual Purchased Energy (GWh)	19,802	25,271	32,610	42,621	56,330	75,573
- Peak Demand (MW)	3,276	4,181	5,395	7,051	9,319	12,503
- Load Factor	0.69	0.69	0.69	0.69	0.69	0.69
Medium Case						
- Annual Purchased Energy (GWh)	18,655	23,343	29,372	37,187	47,262	60,520
- Peak Demand (MW)	3,086	3,862	4,859	6,152	7,819	10,013
- Load Factor	0.69	0.69	0.69	0.69	0.69	0.69
Low Case						
- Annual Purchased Energy (GWh)	17,508	21,459	26,353	32,420	39,830	49,023
- Peak Demand (MW)	2,897	3,550	4,360	5,364	6,590	8,111
- Load Factor	0.69	0.69	0.69	0.69	0.69	0.69

Source: JICA Study Team

As the result of peak demand forecast, the calculated peak demand in 2015 using Load Factor (0.69) was 3,086MW, while the actual peak demand was recoreded "3,300MW" on August 3, 2015.

This difference seems to be caused by unexpected increase in temperature in August 2015. The Elastic

Coefficient for Load Factor (0.93), which is calculated by JICA Study Team based on the historical data of demand with temperature in the period of 2011-2015, shall be considered. Therefore, Load Factor shall be corrected to 0.64 (0.69x0.93).

The peak demand forecast with condition of "Load Factor=0.64" at 5 years interval in the period of 2015-2040 are shown in Table 4.3-33.

The calculation results every year up to 2040 are shown in Appendix -4.

Table 4.3-33 Peak Demand Forecast (LF=0.64)

	2015	2020	2025	2030	2035	2040
High Case						
- Annual Purchased Energy (GWh)	19,802	25,270	32,610	42,621	56,330	75,573
- Peak Demand (MW)	3,532	4,508	5,819	7,602	10,047	13,480
- Load Factor	0.64	0.64	0.64	0.64	0.64	0.64
Medium Case						
- Annual Purchased Energy (GWh)	18,655	23,343	29,372	37,187	47,262	60,520
- Peak Demand (MW)	3,327	4,164	5,239	6,633	8,430	10,795
- Load Factor	0.64	0.64	0.64	0.64	0.64	0.64
Low Case						
- Annual Purchased Energy (GWh)	17,508	21,459	26,353	32,420	39,830	49,023
- Peak Demand (MW)	3,123	3,828	4,701	5,783	7,104	8,744
- Load Factor	0.64	0.64	0.64	0.64	0.64	0.64

Source: JICA Study Team

Chapter 5 **Generation Development plan**

In formulating a generation development plan a planner should consider that the plan has to show an appropriate plan for the development of generation units by reviewing preconditions such as future demand, supply capacity, required supply reliability and costs. The appropriate plan not only shows a process for improving supply cost and supply reliability in the system, but it must also contribute to a further understanding of the future conditions for the balance between demand and supply in the system.

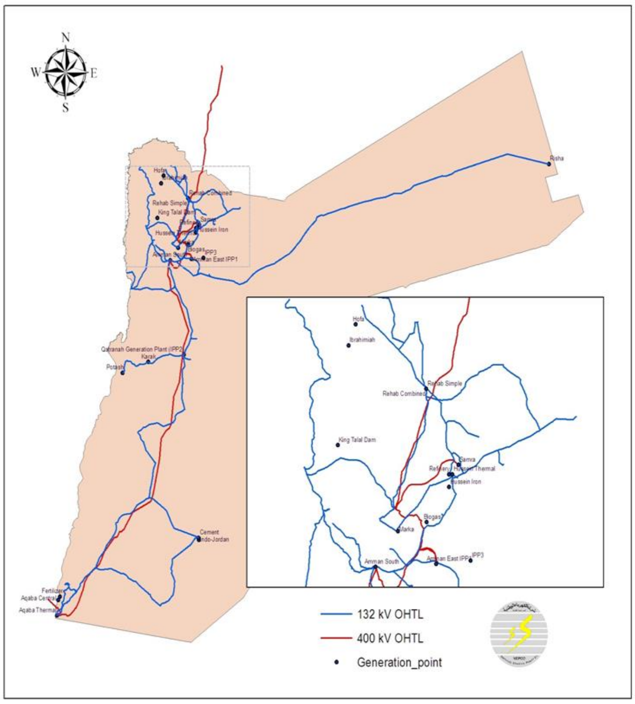
Conversely, if the plan produces an inappropriate development plan, it may lead to serious conditions for the electricity supply in the future such as increased supply cost and a lack of supply capacity in the system.

This chapter discusses the generation development plan for the power system in Jordan up to 2034.

5.1 Generation Development Planning Procedure

5.1.1 Target System for the Study

The power system stretching across the country of Jordan is the target system for power development planning in the Study. At present the northern transmission line (Jordan -Syria) is not connected, so the Jordan system is connecting only to Egypt. Figure 5.1-1 shows the power system in Jordan.



Source: Expansion plan 2014-2020 (NEPCO)

Figure 5.1-1 Power System in Jordan

5.1.2 Workflow of Generation Development Planning

Figure 5.1-2 shows a workflow for the formulation of a generation development plan in the Study.

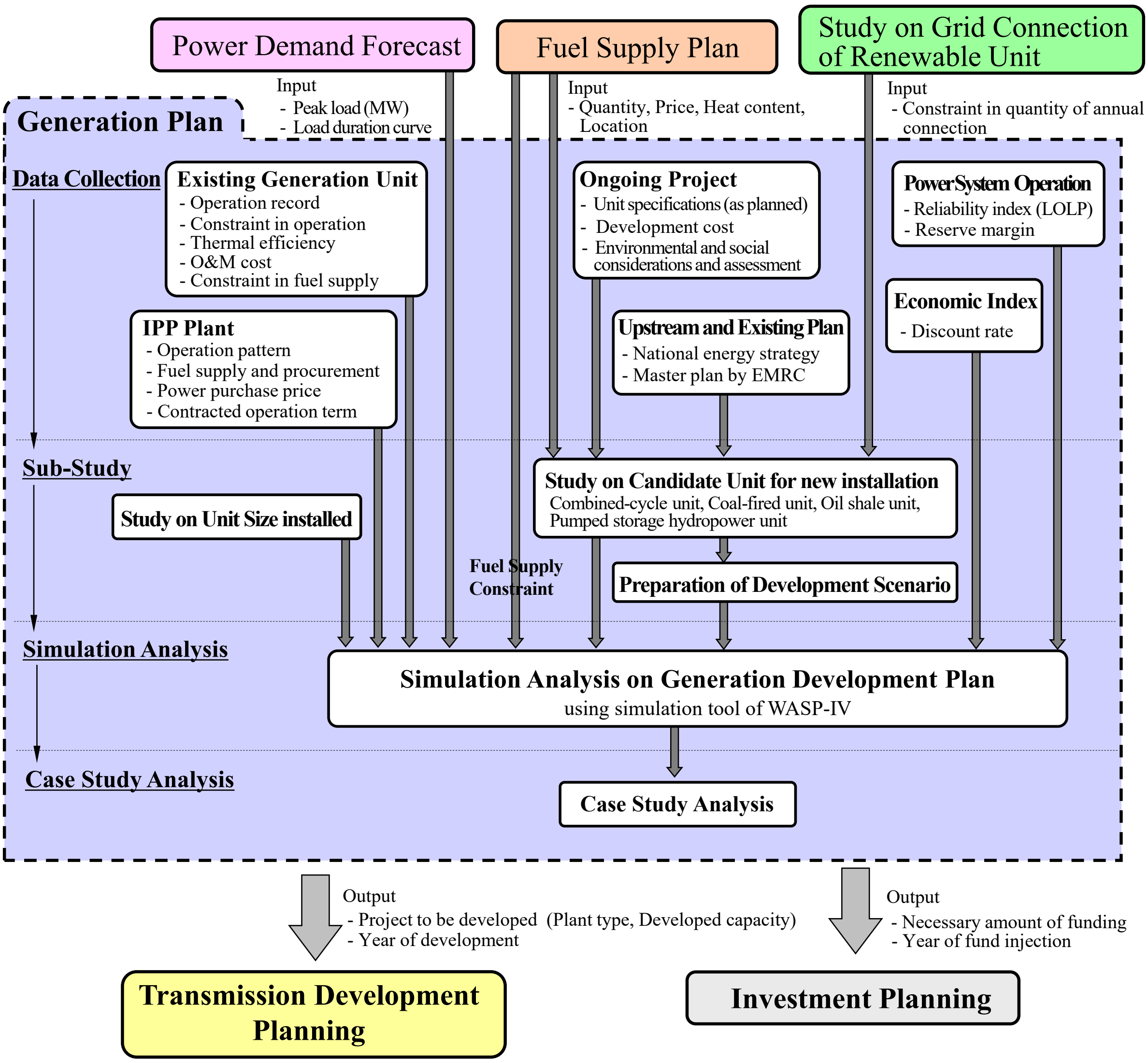


Figure 5.1-2 Workflow for the Formulation of a Generation Development Plan in the Study

5.2 Existing Generation System

Jordan has mainly 10 thermal power plants which are managed by CEGCO, SEPCO or IPPs, and has totally about 3,800[MW] of available net-capacity. In addition, there are several generating components such as renewable energy which is expected to be developed in the near future and some industrial generators. Table 5.2-1 shows the list of main generation units of existing thermal power plants in Jordan.

Table 5.2-1 List of existing thermal power plants

	Power Plant	Unit	Available Capacity (sent out) [MW]	Location	Commissioning Year	Retirement date
CEGCO	ATPS	ST 1	121	Aqaba	1985	31/12/2019
	ATPS	ST 2	121		1985	31/12/2019
	ATPS	ST 3	121		1996	31/12/2030
	ATPS	ST 4	121		1996	31/12/2030
	ATPS	ST 5	121		1999	31/12/2030
	HTPS	ST 4	48	Zarqa	1980	31/12/2015
	HTPS	ST 5	48		1980	31/12/2015
	HTPS	ST 7	48		1984	31/12/2015
	Risha	GT 1	25	Risha	1989	31/12/2016
	Risha	GT 2	25		1989	31/12/2016
	Risha	GT 3	25		1984	31/12/2015
	Risha	GT 4	25		1994	31/12/2016
	Risha	GT 5	25		2005	31/12/2030
	Rehab	GT 10	26	Irbid	1994	31/12/2017
	Rehab	GT 11	26		1995	31/12/2019
	Rehab	CC	260		1996-2005	31/12/2021
	Amman South	GT 9	26	Amman	1995	31/12/2016
SEPCO	Samra I	CC	270	Zarqa	2005-2010	31/12/2033
	Samra II	CC	270		2005-2010	31/12/2033
	Samra III	CC	400		2011-2015	31/12/2035
	Samra IV	GT 7	145		2013	31/12/2038
IPP	IPP 1	CC	360	Amman East	2009	31/12/2033
	IPP 2	CC	360	Qatranah-Karak	2011	31/12/2037
	IPP 3	DE	573	Amman East	2014	31/12/2039
	IPP 4	DE	241	Amman East	2014	31/12/2039
Available Capacity [MW]		3831				

Source: JICA Study Team based on NEPCO data "Expansion plan 2014-2020"

5.3 Generation Development Plan by NEPCO

5.3.1 Outline

NEPCO formulates a generation expansion plan every year after 2010. The plan covers the NEPCO power system for all of Jordan such as existing generator power plants, candidate power sources and fuel supply. The planning period is for the next 5 - 25 years.

Table 5.3-1 Technical Plan drawn up by NEPCO

Plan	Year				
	2010	2011	2012	2013	2014
Power Demand Forecast	Electricity Demand Forecast 2010-2040	Electricity Demand Forecast 2011-2040	—	—	Electricity Demand Forecast 2014-2040
Generation Development	—	Generation Expansion Plan 2011-2040	Generation Expansion Plan 2012-2040	Generation Expansion Plan 2013-2020	Generation Expansion Plan 2014-2020
Power System	Transmission & Substation Plan 2010-2020	—	—	—	—

Source: JICA Study Team

5.3.2 Operational Plan of Power Plants

Table 5.3-2 shows latest version of the generation development plan drawn up by NEPCO (2015~2034). NEPCO plans to introduce several kinds of generators such as Oil Shale and Nuclear while considering the retirement of some existing thermal power plant. Each data is to be confirmed to NEPCO.

5.3.3 Gas Fired Thermal Power

There are two gas fired thermal power projects which are already decided to develop in 2016, one is Samra ST4 and another is ACWA according to latest Generation Development Plan which is shown in Table 5.3-2. Samra ST4 project is to add steam turbine for phase IV gas turbine so that it is remodeling to combined cycle, and the project will start operation in 2018.

On the other hand, the ACWA project which is so called IPP5 is signed Power Purchase Agreement on January, 2016. IPP5 is planned to replace existing Hussein thermal power plant and will also start operation in 2018. The facility designing is 485MW CCGT which runs on Natural gas as the primary fuel and Light Diesel Oil as the secondary fuel. The total investment cost of this project is US$ 460 million and uses GE Energy's 9E turbines. The operation and maintenance of IPP5 will be undertaken by CEGCO.

5.3.4 Renewable Energy

(1) Development Plan

Table 5.3-3 shows the development plan of renewable energy in Jordan. NEPCO sets a target introducing totally about 1,700MW of renewable energy to Jordan system by 2020. In advancing toward this goal, NEPCO have concrete plan to operate totally 1,000MW capacity of the energy. In addition, one of the projects has been already committed, and furthermore, JORDAN Wind PROJECT at Tafila has already operated on 31th Aug, 2015.

Table 5.3-2 Generation Development Plan in Jordan drawn up by NEPCO

(MW)

		Available Net-Capacity																			
Power Plant	**Unit**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
ATPS	ST 1	121	121	121	121	121															
ATPS	ST 2	121	121	121	121	121															
ATPS	ST 3	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121				
ATPS	ST 4	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121				
ATPS	ST 5	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121	121				
HTPS	ST 4	48																			
HTPS	ST 5	48																			
HTPS	ST 7	48																			
Risha	GT 1	25	25																		
Risha	GT 2	25	25																		
Risha	GT 3	25																			
Risha	GT 4	25	25																		
Risha	GT 5	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25				
Rehab	GT 10	26	26	26																	
Rehab	GT 11	26	26	26	26	26															
Rehab	CC	260	260	260	260	260	260	260	260	260	260	260									
Amman South	GT 9	26	26																		
Samra	I	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	
Samra	II	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270	270
Samra	III	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Samra GT7	IV	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145	145
Samra ST4	IV				75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
IPP 1, Amman East	CC	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
IPP 2, Qatrana	CC	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
IPP 3, Amman Asia	DE	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573	573
IPP 4	DE	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241	241
ACWA	CC				485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485
Attarat	Oil Shale 1						235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
Attarat	Oil Shale 1						235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
NPP	Nuclear1									1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
NPP	Nuclear2											1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Total Capacity		**3,831**	**3,662**	**3,561**	**4,095**	**4,095**	**4,297**	**4,297**	**4,297**	**5,297**	**5,297**	**6,297**	**6,037**	**6,037**	**6,037**	**6,037**	**6,037**	**5,649**	**5,649**	**5,649**	**5,379**

Source: JICA Study Team based on NEPCO data "Energy Balance 2015-2030"

Table 5.3-3 Development Plan of Renewable Energy

Wind

Developer	Size (MW)	Site location - Connection	Status	Expected Year of Operation
JORDAN Wind PROJECT -Tafila	117	Tafila Area - Tafila S/S (Rashadiya-Hasa OHTL)	PPA Signed	2015
King Hussien University	80	Maan Area - King Hussien S/S (Maan-Rashadiya 132kV OHTL)	EPC Contract Project	2016
KEPCO (Fujaij)	89	Fujiej Area - Fujiej S/S (Maan- Rashadiya 132 kV OHTL)		2018
Green Watts Renewable Energy	83	Rajif Area Qwera- Maan 132kV OHTL		2018
KOSPO (Tafila)	50	Near Tafila area	After Maan 400/132kV	2019
Xenel	50	Near Tafila area	After Maan 400/132kV	2019
Hecate	45	Near Ishtafina		2019
Mass	100			2019
Total	614			

Solar

Developer	Size (MW)	Site location - Connection	Status	Expected Year of Operation
Shamsuna	9.8	Aqaba 132/33 kV Thermal S/S	PPA Signed	2016
Scatec	10	Maan 132/33 kV Substation	PPA Signed	2016
Jordan Solar One	20	HOSHA Area - Al Hasan Industrial 132/33 kV SS	PPA Signed	2016
Bright Power	10	Maan Development Area- MDA Substation	PPA Signed	2016
Catalyst Private Equity	21		PPA Signed	2016
CEC	10		PPA Signed	2016
EJRE	20		PPA Signed	2016
Ennera	10		PPA Signed	2016
Martifer	10		PPA Signed	2016
Greenland	10		PPA Signed	2016
Shams Ma´an	52.5		PPA Signed	2016
SunEdison	20.5		PPA Signed	2016
PV Qwera	75	Qwera Area - Qwera S/S (DESI – Qwera OHTL)	EPC Contract Project.	2017
Hareon Swiss	50			2018
Fotowatio, FRV	51			2018
Sun Rise	50			2018
Saudi oger	50			2018
Masdar	200			2018
PV Round 3	400			2019
Total	1,080			

Source: JICA Study Team based on NEPCO data

(2) Tariff system for renewable energy

Jordan has introduced tariff system for renewable energy in 2012. Renewable energy is bought by NEPCO as single buyer from IPPs. In Jordan, unlike in Japan, the purchase price of renewable energy by project is determined between NEPCO and an IPP such that it does not exceed an upper limit price. Table 5.3-4 shows purchase price of renewable energy in Jordan. The purchase price of solar energy is drastically dropped from 2017, on the other hand, that of wind energy is not changed through the period.

Table 5.3-4 Purchase price of renewable energy in Jordan (upper limit price)

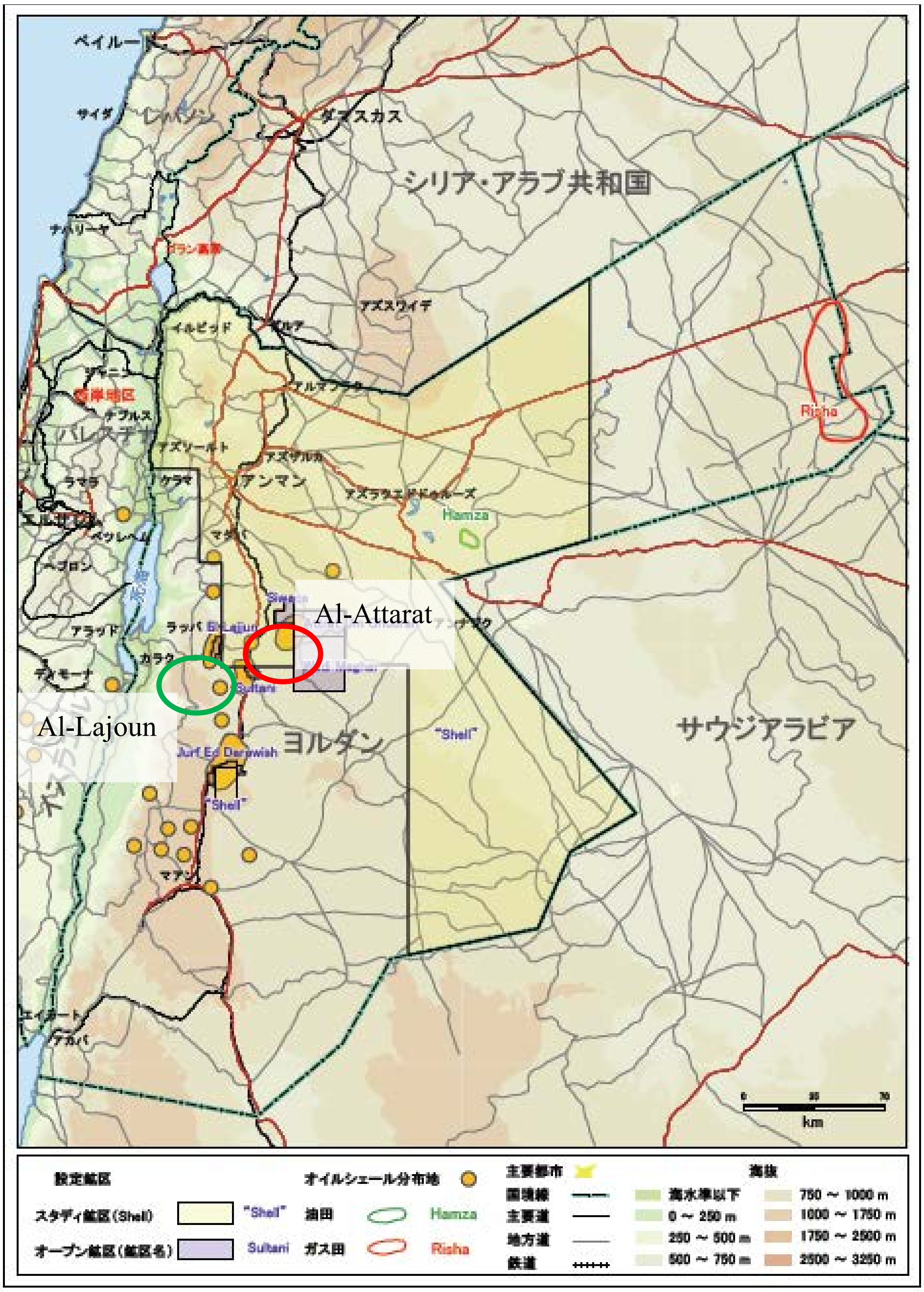
Type	Purchase price (Wind)		Purchase price (Solar)	
	Fils/kWh	USD/MWh	Fils/kWh	USD/MWh
2015	84.4	119.0	120.0	169.3
2016	85.0	119.9	120.0	169.3
2017	82.5	116.4	50.0	70.5
2018	80.0	112.8	50.0	70.5
2019-2034	75.0	105.8	50.0	70.5

Source: JICA Study Team based on NEPCO data

5.3.5 Oil Shale

In Jordan, the amount of oil shale is estimated approximately 4 billion tons, which is prospected anywhere from Ma'an to Yarmouk River. A project for constructing new thermal power plants with direct combustion system using oil shale is planned at both Al-Attarat site and Al-Lajoun site.

The generation technology which uses direct combustion of oil shale has been adopted in Estonia since 1924. At the present day, direct combustion of oil shale is existing technology because they have chosen 80% composition of electrical source in Estonia.



Source: Japan Oil, Gas and Metals National Corporation (JOGMEC)

Figure 5.3-1 Distribution map of oil shale in Jordan

(1) Al-Attarat

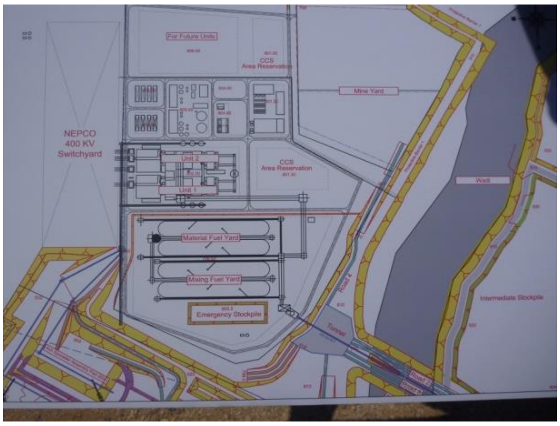
We conducted a field survey at developing site of Attarat Power Company (APCO). This project has been signed Power Purchase Agreement (PPA), so that it seems to be close to start constructing.

The following Table 5.3-5 and Figure 5.3-2 shows results of hearing investigation and field survey.

Table 5.3-5 Al-Attarat generation plan

Contents	Substances
Industrial company (Consortium) Attarat Power Company(APCO)	Gungdong YUDEAN (45%) Chinese private company YTL (45%) Malaysian private company Enefit (10%) Estonian national company
Location	Attarat Um Ghudran
EPC	Guangdong Power (China) Boiler：Alstom, ST/Gen: Siemens
Generating Power	275MW (Gross) ×2units
Amount of heat value, ash, sulfur	Approx.3.5MJ/kg (LHV）、Approx.65%、Approx.2.4%
Main suchedule	2012 complete survey of geological condition and water quality 2013 complete environmental impact study 2016 finance close / groundbreaking (plan) 2018 commencement of commercial operation (plan)
Generation Facilities	Planning expansion of 2 units in the future CFB (Circulation Fluidized Bed Boiler) Secure the land to build Carbon captured and storage (CCS) Oil shale storage：10days and extra 4days for emergency stock
Distance to existing transmission line(400kV)	Approx. 50 km (transformer and transmission line will be owned by NEPCO)
Method of mining	Surface mining
Water source	Taking the water is well or rain water. (There is a winterbourne called "Wadi", which is filled by rain in winter.) Groundwater layer is at 420m and 1080m below ground. Because of water quality, the plan of groundwater use is that 420m layer is for plant and 1080m layer is for mining oil shale.
Land form	Land form is somewhat contoured desert area
PPA	26.5years by COD (extendible 40years at the user's option)

Source: JICA Study Team based on NEPCO data



Site layout　　　　Plant layout

Boring survey point of water quality　　　　Boring survey point of Oil shale

Oil shale

Source: JICA Study Team

Figure 5.3-2　Development status of Al-Attarat project

(2) Al-Lajoun

The project of planning to construct power plant at Al-Lajoun area signed MOU with Jordan Industry and Trade Ministry in 2013. This project is under accommodation at the moment.

Table 5.3-6 Al-Lajoun generation plan

Contents	Substances
Industrial company (Consortium)	Al Hamed Enterprise United Arab Emirates company Chinese enterprise HTG Shandong Electric Power Construction Corporation（SEPCOIII) Chinese company
Location	Al-Lajoun
Generating Power	Around 540MW
Main schedule	2013 Signing MOU of project with Jordan Industry and Trade Ministry

Source: JICA Study Team based on NEPCO data

5.3.6 Nuclear Power Generation

As for nuclear generation development, Jordan Atomic Energy Commission accepted the atomic power technology by Russia, and a Russian company, ROSATOM promotes to prepare the development of nuclear power plants. Jordan and Russia government agreed framework agreement of nuclear power plant construction in May 2015. Its construction is aimed to start in 2016. The operations of the first unit of 1,000MW class and the second unit of 1,000MW class are aimed to start in 2023 and 2025 serially. It is a problem that the development scale is more than the power grid capacity. Furthermore, the structures of construction and operation also have many issues.

In spite of those problems, nuclear development is national commitment in Jordan because there is rich source of uranium as a by-product of phosphate which is main product in Jordan.

5.3.7 Fuel Procurement Plan

(1) HFO

In Jordan, all amount of HFO in common with diesel oil as it is showed later is imported. In addition, Jordan imports two types of HFO, one is containing 3.5% sulfur and another is containing 1% sulfur.

(2) Diesel Oil

As well as HFO, all consumption of domestic demand is covered by imported diesel oil. According to active expansion of fuel storage tanks, they are possible to supply fluctuating domestic demands of diesel oil as for depending on market price.

(3) NG

Although Jordan used to import NG from Egypt by using undersea pipeline a few years ago, there is not existing imported NG by using gas pipeline. However, there are procurement plans to import NG from several countries which are shown following Table 5.3-7. Alternatively the following plan from Egypt NG is scheduled to restart because there is an existing contract.

Table 5.3-7 NG procurement plan

Exporter	Supply(tentative) [MMsfcd]	Start up(tentative)
Mediterranean	200~250	2021
Palestine	175	2021
Egypt	250	2018

Source: JICA Study Team based on NEPCO data

(4) LNG

Instead of importing NG through Arab gas pipeline, Jordan started to import LNG as a new energy source using a Floating Storage and Regasification Unit (FSRU). The LNG receiving facility by FSRU placed at Gulf of Aqaba and connected to existing Arab pipeline as it is able to supply regasification NG for pipeline network in Jordan. This facility started up on July 2015, which contracted 5 years including optional 5 years expansion. Furthermore, Jordan government and Egypt government signed to export NG to Egypt from FSRU by using existing undersea pipeline for two years.

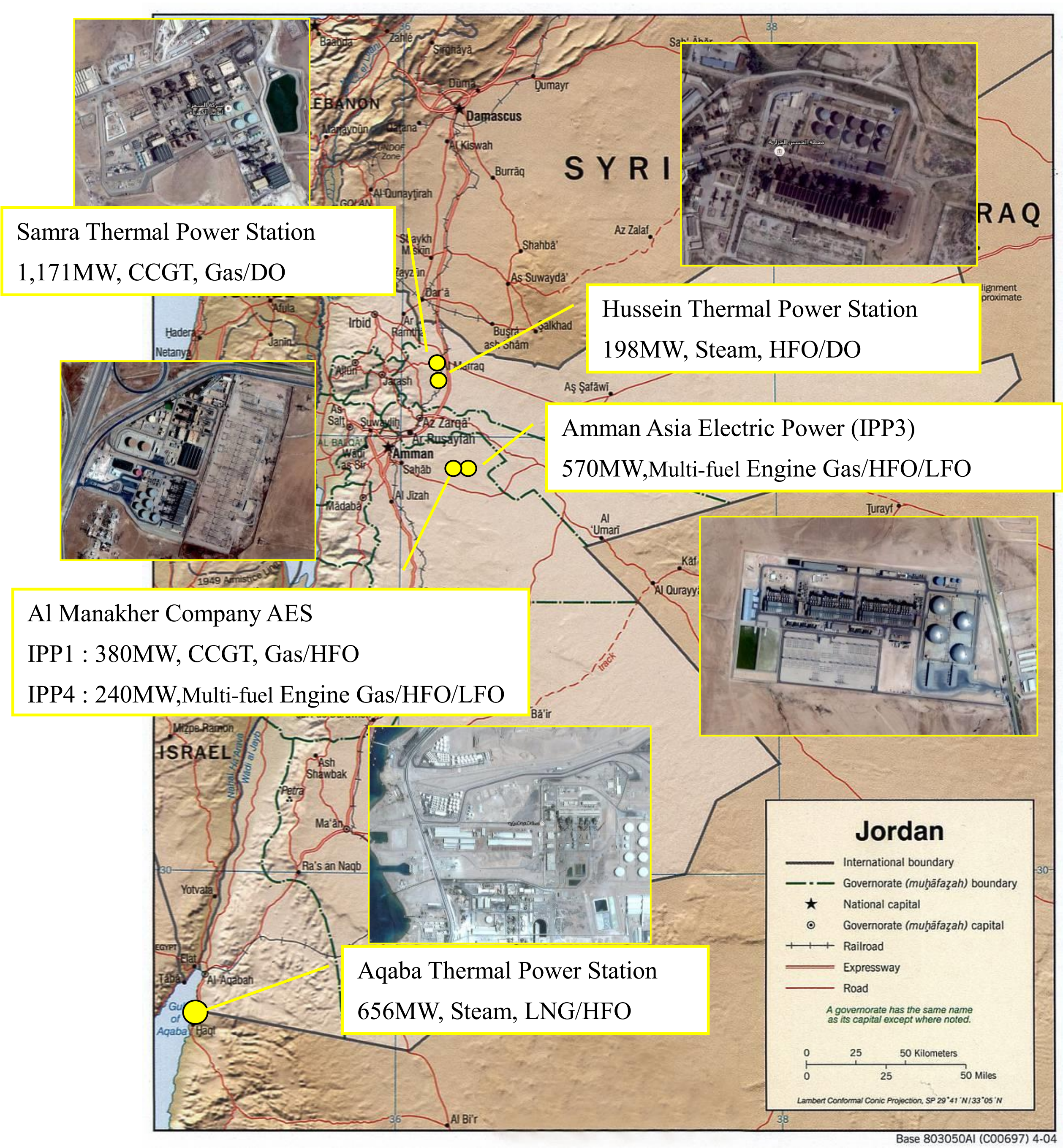
Although the future plan of importing LNG depends on the progress of the new NG procurement plan as previously explained, it is necessary to import LNG from the viewpoint of ensuring the diversity of fuel procurement sources.

5.4 Candidate site for development

5.4.1 Improvement existing generation facilities

(1) Compendium data of existing generation facilities

JICA study team surveyed several thermal power plants; one is Hussein Thermal Power Station (CEGCO) which is an aged thermal power station, another is Aqaba Thermal Power Station (CEGCO) which is a middle-aged one, another is Samara Thermal Power Station (SEPCO) which is the most-advanced one, the other is owned by an IPP. The following Figure 5.4-1, Table 5.4-1 and Table 5.4-2 show compendium data of those survey sites.



Source: JICA Study Team based on CEGCO web site and Google Earth

Figure 5.4-1 Site survey places of thermal power station

Table 5.4-1 Compendium data of existing generation facilities (CEGCO, SEPCO)

Company	Central Electricity Generating Company		Samra Electric Power Company
Site	Hussein thermal power plant	Aqaba Thermal Power Plant	Samra
COD	Unit4,5:1980 Unit7:1984	Unit1,2:1985 Unit:3,4,5:1995	2005,2006,2007,2208,2010, 2011,2013,2015
Type	Steam	Steam	CCGT
Capacity	33MWx3units (all : Decommission) 66MWx4uinits (1unit : Decommission)	130MWx5units	GT1,2,3,4:100MW GT5,6:142.5MW GT7:146MW ST1,2:100MW ST3:140MW
Fuel	HFO/DO	Gas/HFO/DO	Gas/DO
Vender (Boiler)	Kawasaki Heavy Industries	Unit1,2:MHPS Unit:3,4,5:ABB	Kawasaki Heavy Industries
Vender (Turbine)	Fuji	Unit1,2:Franco tosi Unit:3,4,5:ABB	GT1,2,3,4:GE ST1,2:Fuji GT5,6:Alstom ST3:Doosan
Generation (2014)	982,061 MWh	4,126,425 MWh	4,521,000 MWh
Thermal efficiency (2014)	25.73%	34.25%	Phase1:43.9%(CCGT) Phase2:43.2%(CCGT) Phase3:28.6%(SCGT) Phase4:27.3%(SCGT)
Forced outage (2014)	3.79%	3.20%	2.3%
Planed outage (2014)	3.06%	6.11%	4.1%

Source: JICA Study Team and CEGCO web site

Table 5.4-2 Compendium data of existing generation facilities (IPP)

	Independent Power Producer		
	Al Manakher Company AES (IPP1)	Amman Asia Electric power (IPP3)	Al Manakher Company AES (IPP4)
COD	2009	2014	2014
System	CCGT	Multi-fuel Engine	Multi-fuel Engine
Capacity	380MW	15MWx38units	15MWx16units
Fuel	Gas/HFO	Gas/HFO/LFO	Gas/HFO/LFO
Vender	GT:Ansald, ST:Fuji	Wartsila	Wartsila

Source: JICA Study Team

(2) Overview of the Survey

JICA study team surveyed how to reduce the cost that thinking point of equipment and operation side at existing generation facilities. JICA study team had an interview as follows at each power plant: especially, equipment improvement and developing maintenance tools (jigs) in terms of equipment, and make a special effort to improvement in performance management, checkup management, operation and trouble management in terms of operation.

(i) Hussein Thermal Power Station（HTPS)

JICA study team surveyed HTPS which is an aged thermal power plant and has been operated since 25 years ago. At the present time, 4 of 7 units have already been decommissioned, the other 3 are planned to stop in end of 2015. Considering about those situations, it is needed to pay much cost to equipment improvement. Then, JICA study team surveyed operation knowhow for long term operating in this power plant, from the viewpoint of sharing information with CEGCO.

Table 5.4-3 Results of survey at HTPS

Item	Type of work	Results of hearing and field survey
Operation	Trouble management	In the case of equipment failure, CEGCO determines the causes using tree diagram, etc. The information about the results of equipment failures are shared only in On-The-Job Training (OJT) activities, and the framework that the information is shared within this plant and with other plants has not been established.
	Checkup management	The major inspection of ST and Boiler is held once every four years. In addition, short examination is held every year. But, major inspection of GT is put in interval by manufacturer’s suggestion.
		In CEGCO, there are employees in charge of maintenance at each power plant. In rare cases, someone dispatches to other power plant.
		A work place where equipment parts except GT parts are repaired and produced is provided inside this power plant. GT parts are provided to each substation by a maintenance shop in Amman city.

Source: JICA Study Team

Central Control Room

Turbinebuilding

Appearance of generation facilities(Unit No.7)

Source: JICA Study Team

Figure 5.4-2 Hussein Thermal Power Station

(ii) Aqaba Thermal Power Station (ATPS)

JICA study team surveyed ATPS which is a middle-aged thermal power plant. ATPS is the largest power plant of CEGCO, and also the second largest power plant in Jordan: the largest one is Samra power station. Although the operation rate of it is very high as of 2015, the decommissioning of its unit 1 and unit 2 is scheduled in 2019. Its unit3, unit4 and unit5 are also scheduled to be decommissioned in 2030. JICA study team surveyed equipment investigation and operation at ATPS with a view to equipment improvement.

Table 5.4-4 Results of survey at ATPS

Item	Type of work	Results of hearing and survey in site
Equipment	Equipment investigation	Two small hydroelectric generators are installed at the spillways for cooling water, one is 2.4MW at the spillway of unit 1, 2 the other is 3.6 MW at the spillway of unit 3, 4, 5. In addition, ATPS has an emergency spillway.
		The boilers were updated in 2003 from HFO single fuel

		combustion type to multi- fuel combustion type in which NG can be used.
		Controlled equipment of unit 1, 2 has already been updated.
Operation	Checkup management	They set up several analysis rooms; such as chemical analysis rooms for water, oil, gas and mechanical analysis rooms for NDT, vibration analysis and thickness measurement mahines, and also have motor rewiring equipment.
		The Lock Out Take (LOT) system supports isolation of valve in the case of maintenance.
	Trouble management	Although they operate 4 units in same CCR, they do not take measures for misunderstanding unit management.

Source: JICA Study Team

Central control room (unit 1, 2)

spillway small hydroelectric generator (Phase2)

Appearance of generation facilities

Source: JICA Study Team

Figure 5.4-3 Aqaba Thermal Power Station

(iii) Samra Electric Power Company (SEPCO)

JICA study team surveyed Samra Electric Power Company (SEPCO) which is the most advanced and the largest thermal power plant in Jordan and is placed at Samra. Samra Thermal Power Station is a combined cycle gas turbine (CCGT) power plant and the operation rate is very high at the present time. They plan to construct 75MW ST facility to convert GT No.7 facility to CCGT on "phase 4" in 2018. Then, JICA study team surveyed several points of SEPCO because the operation rate will be so high that they plan to continue constructing CCGT.

Table 5.4-5 Results of survey at SEPCO

Item	Type of work	Results of hearing and survey in site
operation	Checkup management	There is no chance to learn how to manage performance in-house because the manufacturer conducts all tasks related to performance management.
Equipment	Equipment investigaton	Because being a CCGT, the power output is influenced by air temperature. It is a serious problem for Jordan that power output decreases in summer due to high air temperature of over 35 degrees.

Source: JICA Study Team

Central control room

Appearance of generation facilities (UnitNo.1,No,2)

Appearance of generation facilities (UnitNo.7)

Source: JICA Study Team

Figure 5.4-4 Samra Power Station

(iv) Amman Asia Electric Power (IPP3)

IPP3 is a thermal power plant with a multi – fuel engine which can combustion gas, HFO and LFO, and started its operation in 2014. JICA study team surveyed this power plant considering operation on peak and middle load.

Table 5.4-6 Results of survey at IPP3

Item	Type of work	Results of hearing and survey in site
Equipment	Equipment investigation	They can control the power in increments of 1MW, so that it is the most suitable power plant for absorbing power fluctuation of renewable energy. The loading oil equipment can treat 20 tankers for HFO or 6 tankers for LFO at a time.
Operation	Checkup management	They inform visitors of the safety instruction. They put in their best efforts to secure safety.

Source: JICA Study Team

Central control room

Generation facility building

Appearance of generation facilities

Source: JICA Study Team

Figure 5.4-5 IPP3

(v) Al Manakher Company AES (IPP1,4)

IPP1 is the first gas turbine combined cycle thermal power plant in Jordan startup in 2009 and IPP4 is a multi-fuel engine power plant startup in 2014. IPP1 is operated for base load, and IPP4 for peak load.

Table 5.4-7 Results of survey at IPP1, IPP4

Item	Type of work	Results of hearing and survey in site
Equipment	Equipment investigation	IPP1 equipment can switch fuel such as gas and oil during operation. Fuel can be switched in 5 minutes while generation output is suppressed to 50%.
		IPP1 has the output reduction in summer season can be relieved.
Operation	Checkup management	They inform visitors of the safety instruction. They put in their best efforts to secure safety.

Source: JICA Study Team

Central control room

Appearance of generation facilities (IPP1)

Appearance of generation facilities (IPP4)

Source: JICA Study Team

Figure 5.4-6 IPP1 and IPP4

(3) The summary of survey results

It was confirmed that the suppliers as SEPCO, CEGCO and each IPP have enough conscious about cost reduction through the site surveys.

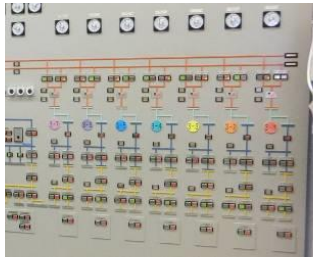
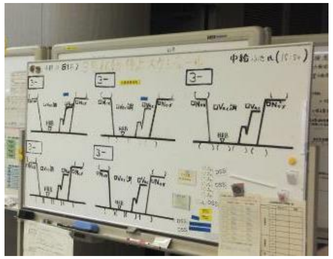
The current situation at each power plant was also confirmed and short-term cost reduction measures are proposed in consultation with members of each power plant as shown in Table 5.4-8.

Table 5.4-8 Proposed measures for cost reduction

Category		Cost reduction method	Contents
Equipment	Equipment investigation	With reinforcing or remodeling equipment, to improve thermal efficiency and output power is led to reduction of maintenance and operation cost.	
		Condenser cleaning equipment	The preservation of condenser vacuum and the damage prevention of pipe are led to reduce cost of maintenance and operation.
		Suction cooling	To reduce the suction air temperature of GT in summer is led to reducing cost of operation because it prevents the reduction of GT output and thermal efficiency. A 1% improvement of thermal efficiency can be expected.
		HEPA filter	To reduce washing times of compressor and to inhibit efficiency degradation of compressor are led to reduction of maintenance and operation cost.
		Additional GT for ST	To put in additional GT which can take a part in enhancing output and efficiency is led to reduction of operation cost.
	Maintenance tools (jigs)	Using maintenance tools (jigs) which can take over shortening inspection term is to reduce maintenance cost.	
		Useful machine for maintenance	 Ex) Bolt polisher  Ex) Applicator for protecting from seizing bolts Reduction maintenance cost from reducing manpower and time.

<table>
<tr><td rowspan="2"></td><td></td><td>Checkup cradle</td><td>  Inspection cradle is useful for the worker to check up and maintain equipment more safely and efficiently, and it contributes to reduce inspection period and maintenance cost.
Ex) Stator bane inspection cradle Ex)fuel nozzle inspection cradle</td></tr>
<tr><td>Maintenance tools (jigs)</td><td>Electrical cradle for rotating body</td><td> This tool is useful for the worker to check up and maintain equipment more safely and efficiently in spite of reducing manpower, and it is contributes to reduce inspection period and maintenance cost.
Ex) Electrical cradle for rotating body</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="6">Operation</td><td rowspan="5">Operating method</td><td colspan="2">To optimize operation method is led to reduction of maintenance and operation cost</td></tr>
<tr><td>Lowest output</td><td>To decrease lowest output is led to reducing fuel cost of start and stop.</td></tr>
<tr><td>Control condenser vacuum</td><td>To prevent decrease of efficiency due to low vacuum or high vacuum by maintaining vacuum vlue at the design value contributes to reduce operation cost.</td></tr>
<tr><td>GT compressor cleaning</td><td>To optimize cleaning interval is led to enhance efficiency, then it contributes to reduction of maintenance and operation cost.</td></tr>
<tr><td>GT IGV aperture</td><td>To modify larger position at full open condition is led to enhancing output, then it is led to avoid useless constructing new power plant.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

	Plant performance management	To manage performance enables detecting deterioration of performance and improvement. It contributes to reduce maintenance cost.	
		Central monitoring system	The operation cost can be reduced by comparing other power plants and reducing mam-power.
		Abnormal condition monitoring system	It can reduce maintenance cost in case of grasping abnormal condition which take less damage the equipment. The maintenance cost can be reduced by grasping contributes to reduce.
	Maintenance management	To lengthen inspection interval contributes to reduce operation and maintenance cost.	
		Interval management	It is possible to lengthen interval between inspections depending on the result of past inspection. To lengthen interval by analyzing the result of past inspections contributes to reduce maintenance cost.
		Remaining life assessment	It is possible to reduce operation and maintenance cost by extending life time of equipment longer than a manufacturer recommended life time depending on the situation.
	Trouble management	Prevention of equipment trouble contributes reduction of operation and maintenance cost.	
		Horizontal development (causal analysis, knowhow sheet, databsase)	 Ex) Knowhow sheet Whenever a trouble of equipment occurs, the causes of the trouble are investigated and database such as “know-how sheet” is prepared. To establish the system under which the knowhow is reflected to operation procedure and equipment design to prevent reoccurrence of a trouble can reduce maintenance cost.
		Unit display identification	Some parts of the units are displayed in the indetification color to be visually and easily identified, it prevents facility damages due to a human error and contributes to reduce

			maitenane cost.  Ex) operating panel in a control room
		Unit radio, whiteboard	  Information sharing with operating people and maintenance people by using tools such as unit radio and whiteboard can prevent an occurance of troubles. Ex) Whiteboard Ex) Unit radio

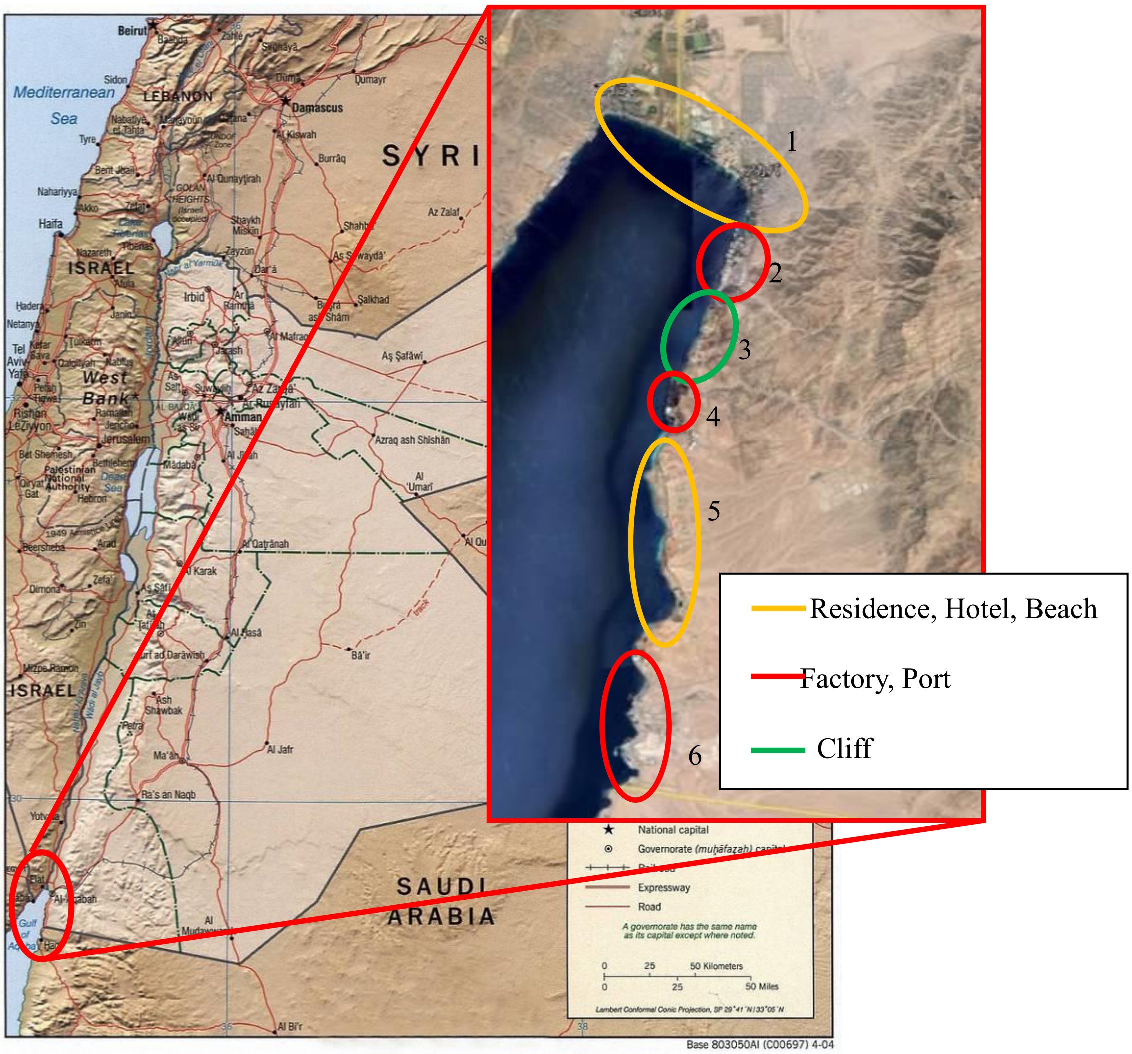
Source: JICA Study Team

5.4.2 Developing New Power Plant to diversify power sources

(1) New coal fired thermal power plant

(i) Site Selection

Considering constructing a new coal fired thermal power plant, there are no domestic coal resources in Jordan. As for it, it is necessary to consider how to manage the power plant with imported coal which is mainly produced from Indonesia, Australia, South Africa, etc. In the case of importing coal from those countries to Jordan, it is required to use huge coal carrier because it takes long time and large quantity for transport coal. In addition, it is necessary for planning the site to locate near the port of unloading for discounting the cost of sending coal equipment and transport cost after unloading coal. Thus JICA study team conducted an area survey in the suburbs of Aqaba city which has only port and harbor for the open sea in Jordan.



Source: JICA Study Team based on Google Earth

Figure 5.4-7 Brief map of candidate site for developing new coal fired power plant

(ii) Overview of the Survey

a) Necessary conditions for constructing coal fired thermal power plant.

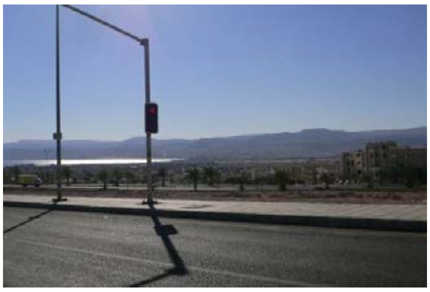
It is required to build not only facilities of generation, water treatment and transformation, but also building facilities of loading coal, coal stockyard, ash treatment facility and ash disposal area. In addition, considering about efficiency of power plant and scale merit of constructing cost, it is necessary to construct a certain huge power plant which requires a larger land than an oil or gas-fired thermal power plant. Furthermore, it is necessary to construct more economical coal fired thermal power plant to fill conditions as follows except for land.

- ✓ Point which can ensure landing bridge with 15m depth so that large coal carriers can come into the port
- ✓ Point is at low altitude from a viewpoint of lower input for pump in case of sea water cooling system at condenser
- ✓ Point is preferred at nearby existing substation because it is necessary to construct large capacity transmission lines.
- ✓ Point is preferred at nearby existing access road suitable for constructing power plant.
- ✓ Point is away from residencia area and tourist area in consideration of environment.

b) Affairs of Aqaba environs

There are many kinds of construction at Aqaba coastline, such as factory or port (Figure 5.4-7: point 2, 4, 6), residence and area of hotel and beach (Figure 5.4-7: point1, 5). Except for that, there is almost 100m high cliff (Figure 5.4-7: point 3) at east side of road.

Industrial zone (Figure 5.4-7: point 6)



Residence (Figure 5.4-7: point 1)

Cliff zone(Figure 5.4-7: point 3)

Beach(Figure 5.4-7: point 5)

Source: JICA Study Team

Figure 5.4-8 Affairs of Aqaba coastline

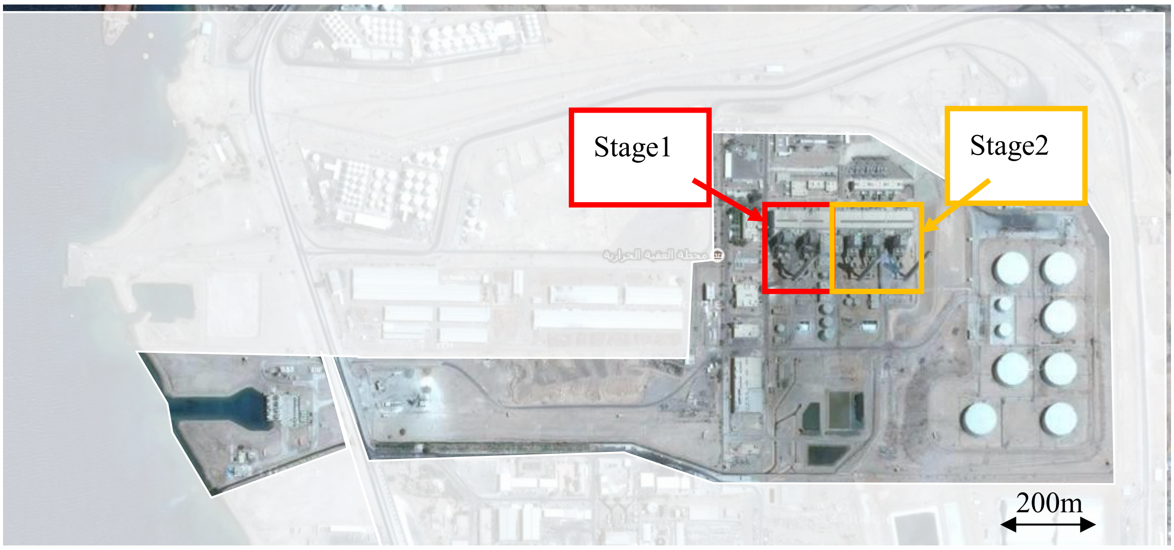
Considering these affairs and condition of (a), it is thought that scrapping existing ATPS and building new power plant (replacement) rather than acquiring new land is the most realistic plan.

c) Affairs about ATPS

Figure 5.4-9 shows the sitemap about ATPS. The site area of ATPS is 52.1ha and building area is 3.27ha, however the substation, the substation monitoring room and the fuel tank belong to NEPCO.

Though unit 1 and 2 which are called "Stage 1" will be scrapped in 2019 by NEPCO generation plan, unit 3, 4 and 5 which are called Stage 2 is not fixed when it will be scrapped.

Almost 170ha land including green belt zone is necessary to build 1000MW class coal fired thermal power plant depending on characteristic of coal, capacity of the coal stockyard and the ash disposal area. Thus it is required to consider expansion of land.



Source: JICA Study Team based on Google Earth

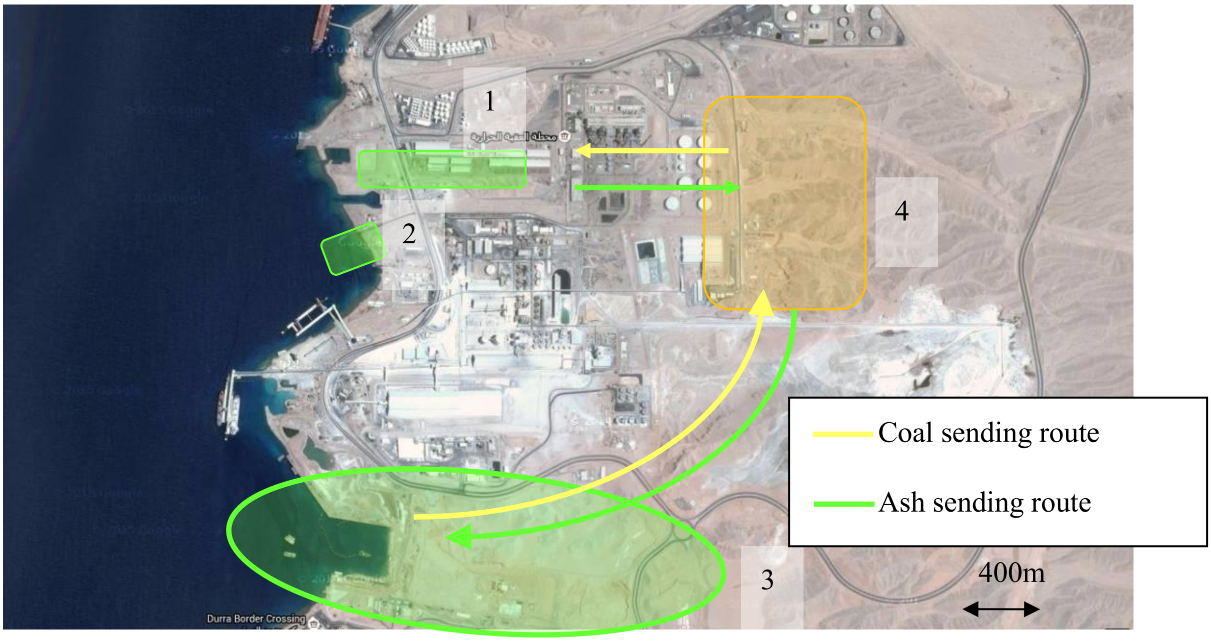
Figure 5.4-9 Existing ATPS sitemap (Figure 5.4-7: enlarged view of point 6)

d) Coordination and recommendation with Aqaba Development Corporation (ADC)

JICA study team confirmed to discuss with ADC the condition of land use around ATPS according to results of field survey at ATPS. Result of discussion is as follows.

- JICA study team considered a possibility of using new prot as unloading coal at nearby existing power plant. However, it become clear that the ADS has already decided that the purpose of a new port would be for another industry business use.
- There is a possibility of expansion at east side of existing power plant for developing coal stockyard and ash disposal area. (Figure 5.4-10: point 4)
- There are closedown warehouses or factories in operation around existing power plant. Although there is less chance to secure landowners on using these area for constructing new power plant according to ADC. (Figure 5.4-10: point 1)

- Although another possible site along the coastline was shown by ADC, it seems to be economically inefficient because the land elevation of developed land for new power plant is high. (Figure 5.4-11)



Source: JICA Study Team based on Google Earth

Overall view (Figure 5.4-7: enlarged figure at point 3)

Wood factory (overall view: point 1)

Confirming point of land owner (overall view: point 2)

Candidate developing site (overall view: point 3)

Source: JICA Study Team

Figure 5.4-10 Near the border of Saudi Arabia

Source: Aqaba Development Corporation (ADC)

Figure 5.4-11 Candidate site for coal fired thermal power
(ADC recommended, Figure 5.4-10: point 4)

(iii) Plan of development coal thermal power plant

(a) Estimated scale of coal fired power plant

JICA study team received the land use data around ATPS from ADC, interviewed with affiliates and conducted field survey. According to these results, the most prospective plan is development at existing ATPS as refered to above (ii). Therefore, JICA study team consider two scenarios one of which is about Ultra Super Critical (USC), and the other, Super Critical (SC). In addition, the total output of new coal fired power plant is 600MW to replace unit 1 and 2 of ATPS which will be decommissioned in 2019.

Table 5.4-9 Comparison of Coal Fired Power Plant

	Single unit (600MW)	Multiple units (2x300MW)
Type of boiler	USC (Ultra Super Critical)	SC (Super Critical)
Thermal Efficiency (HHV)	41% Improved 6% from SC efficiency ⇒lower fuel consumption	35%
Construction cost	2,100 USD/kW 10% higher than SC construction cost	1,900 USD/kW
Fuel cost	83% of SC type unit due to high thermal efficiency	100% (Baseline)
Total Generation cost (Coal price: 55 USD/t)	54.4 USD/MWh	53.2 USD/MWh
CO_2 Emission	830g/kWh	950g/kWh

Although construction cost of USC is higher than that of SC, thermal efficiency of USC is higher than that of SC in case coal price is assumed as $55/ton. But, CO_2 emission is dramatically differnt and CO_2 emission of USC type is approximately 10% less than that of SC type.

(b) Estimated location plan of coal fired power plant

Estimated location plan of USC and SC generation facilities as explained in the previous section are shown as Figure 5.4-12 and Figure 5.4-13, respectively.

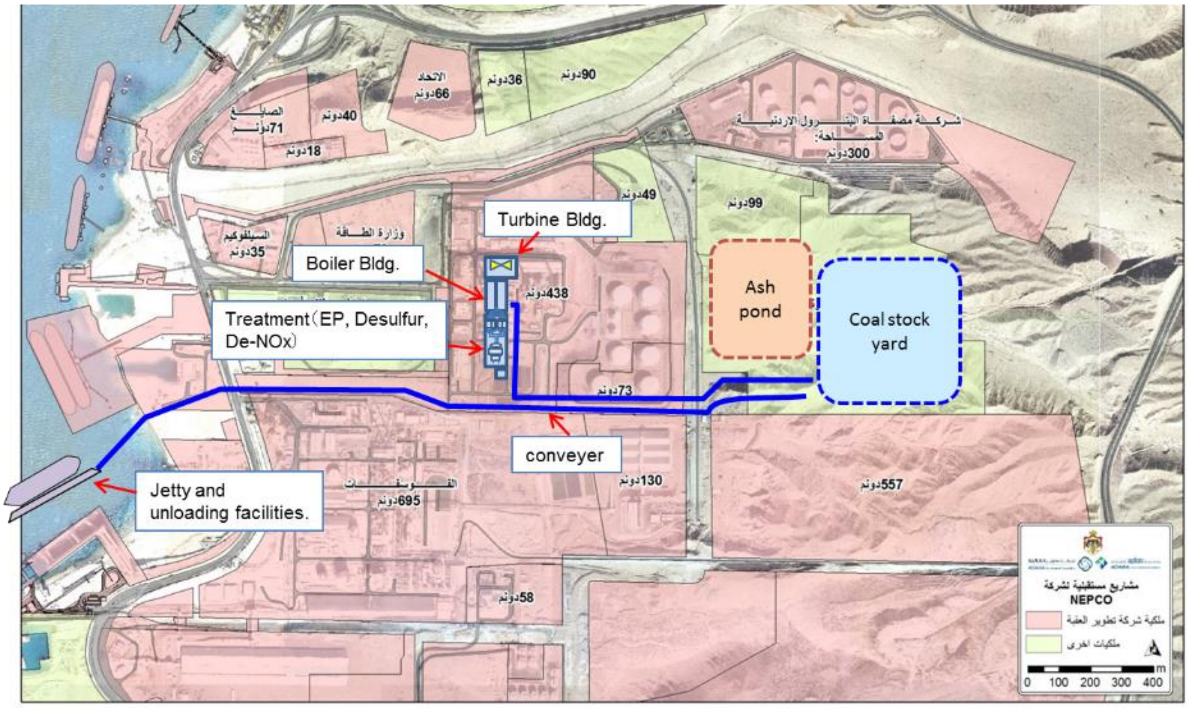


Figure 5.4-12　Location plan of USC coal fired power plant

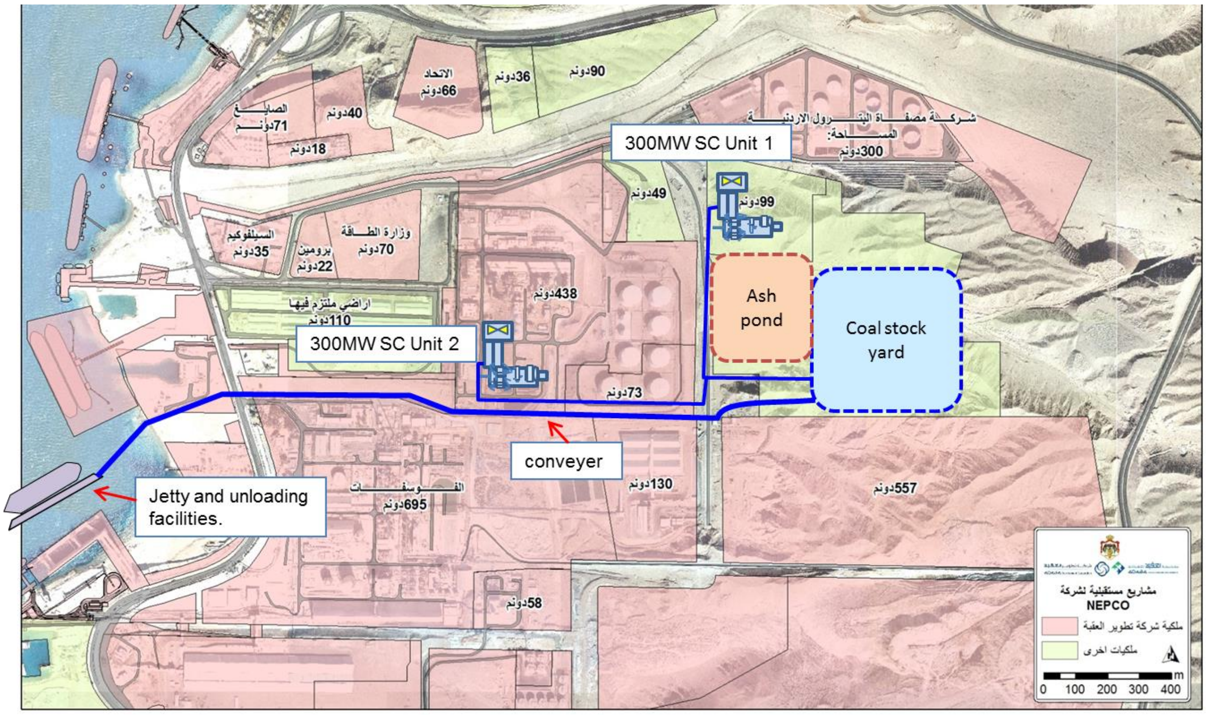


Figure 5.4-13　Location plan of SC coal fired power plant

SC type has promise as constructing new power plant without stop existing one. USC type also has possibility to develop without stop existing power plant depending on the layout of a coal stock yard and an ash pond. The detailed layout is to be determined by feasibility study. However, comparison of boiler type as identified above (a), USC type has more superiority of CO_2 emission than SC type so that it is preferable to choose USC type for new coal fired power plant in light of a global trend of constraining green house gas emission such as Paris Agreement in COP21.

(iv) Thermal discharge influence for introducing coal fired power plant

As an overview of the Aqaba area where ATPS is located, the Gulf of Aqaba is known as one of the richest biodiversity areas in the world. Therefore environmental standards of Aqaba Bay area has been specially regulated which are stricter than that of Jordan national standards. In addition, local government focuses on tourism by utilizing these rich environment of biodiversity so that it is necessary to pay a great deal of thought into environment by developing coal fired power plant. To consider thermal discharge diffusion from USC coal fired power plant with replacing existing unit 1 and 2, threr are coral reefs which are grown close together near public beach and Marine Park where is located north adjacent area of Industrial Zone including ATPS. Thus JICA study team simulate a thermal discharge influence to evaluate environmental issues for developing coal fired power plant.

(a) Regulation of water discharge

Water discharge in Gulf of Aqaba is regulated as seawater temperature at mixing zone. Under the environmental standards of Gulf of Aqaba by ASEZA, temperature differential between the point where is 100 meter away from discharge and surround shall be within 3°C.

Generally, it is said that temperature rise due to heated effluent is less than 2°C which is indicator of coral bleaching. Although, there have been no reports of markedly adverse effects on the coral reefs from ecological surveys of marine life that are periodically conducted by Marine Science Station on commission from ASEZA.

(b) Conditions of prediction about thermal discharge diffusion simulation

For the thermal water discharge simulation, we choose “Simple Prediction Model for Diffusion of Warm-Water Discharge” developed by Central Research Institute of Electric Power Industry. Furthermore, we can calculate simple simulation about discharge from submerged pipes by using this program. The prediction conditions are as Table 5.4-10.

Table 5.4-10 Prediction Conditions of heated water discharge simulation

Contents		Setup Value	Remarks
Effluent condition	ATPS	Current Effluent Amount unit 1,2 10.6m3/s unit 3-5 13.0m3/s Current Effluent tempoareture difference unit 1,2 10.0℃ unit 3-5 10.0℃	unit 1,2 : Submerged discharge (Type : pipe) single φ2,000 (set depth : 20m) ※1 unit 3-5 : Submerged discharge (Type : pipe) single φ2,600 (set depth : 9m) ※1
		Future Effluent Amount new unit 28.5m3/s unit 3-5 13.0m3/s Future Effluent tempareture differnce new unit 10.0℃ unit 3-5 10.0℃	new unit : Submerged discharge(Type : pipe) triple φ2,000 ※2 (set depth : 20m) unit 3～5 : Submerged discharge (Type : pipe) single φ2,600 (set depth : 9m) ※1
Natural Water Temperature(℃)		23.98	Settings by interviws
Discharge plume height(m)		5	Settings by considering enclosed sea area※1
Tidal Currents		M_2 tidal constituent	Settings from the technical literature
Diffusion coefficient(cm2/s)		Entire marine area : Kx=Ky=1×104	simple setting method of costal diffusion coefficient
Meteorological condition	Air tempareture(℃)	24.5	Settings by interviws
	Wind speed(m/s)	4.5	Settings by interviws
Heat exchange coefficient (J/(cm2・s・℃)		8.3×10-3	Setteings from climinal conditions
Calculating area		Calculation range : 10km×15km Size of computational grid : 50m	settings from presuming area of thermal discharge diffusion

※1: Estimate Value

※2: Discharge point of new unit is same as exiting one, and setting of discharge pipe number is due to be not exceeding existing flow.

Source: JICA Study Team

(c) Results of simulation

Results of heated effluent simulation are as follows;

- Rise of temperature due to heated effluent meets within 3°C which is ASEZA's standards.
- Prediction range of heated effluent diffusion is extensively present in almost 500m offshore of coastal resort which has diving spot as shown in Figure 5.4-17. However, the area does not reach the point of shallow coastal zone.

This simulation is not identified the reproducibility of current situation by using effluent simulation result of existing power plant which is done before and result of marine area monitoring.

Also prediction range of heated effluent diffusion is affected by structure of discharge pipe or quantity of discharge flow, so that it is necessary to conduct further study of new outlet.

Given these facts, thermal discharge influence is eco-friendly for coral reef at coastal area.

Further studies are needed in order to consider detail effluent influence including distribution of coral reefs around marine area of power plant.

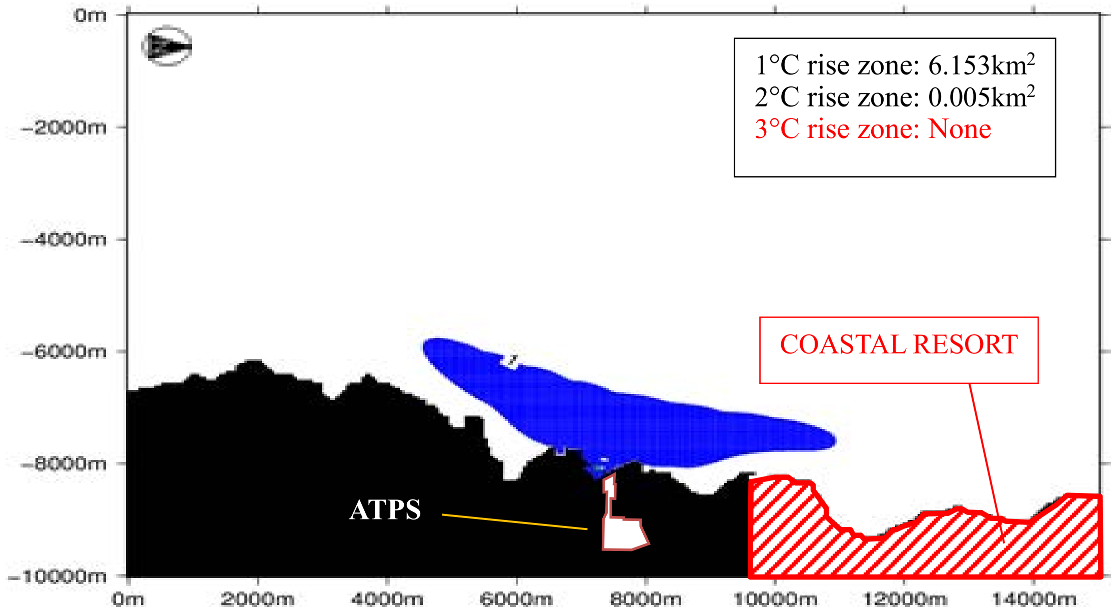


Figure 5.4-14 Prediction range of thermal discharge diffusion

(v) Future policy

It is possible to develop a coal fired power plant at Aqaba area due to previous (iii) and (iv). However it is necessary for technical and economic feasibility estimate to conduct an additional detailed survey about facility layout and so on.

(2) New pumped storage power plant

JICA study team conduct a survey about candidate site for developing a new pumped storage thermal power plant in Jordan.

(i) Object site

There is no large scale hydro power plant in Jordan because of few rivers expected acceptable inflow of the water due to its low rainfall. On the other hand, some water reservoir has been constructed near river in order to hold the water resource in Jordan.

Considering the availability of water resources, JICA study team conducted one survey; seawater pumped storage in the coast area.

(ii) Site Selection

This plant generates electric power utilizing water drop between a water level on upper reservoir and a sea revel treated as on lower reservoir, and pumps seawater to the upper reservoir. Considering the characteristic of the generating system, JICA study team selected Aqaba area as a candidate site for constructing the seawater pumped storage.

(iii) Overview of the Survey

Necessary Site Condition

It is needed following site condition to construct the power plant;

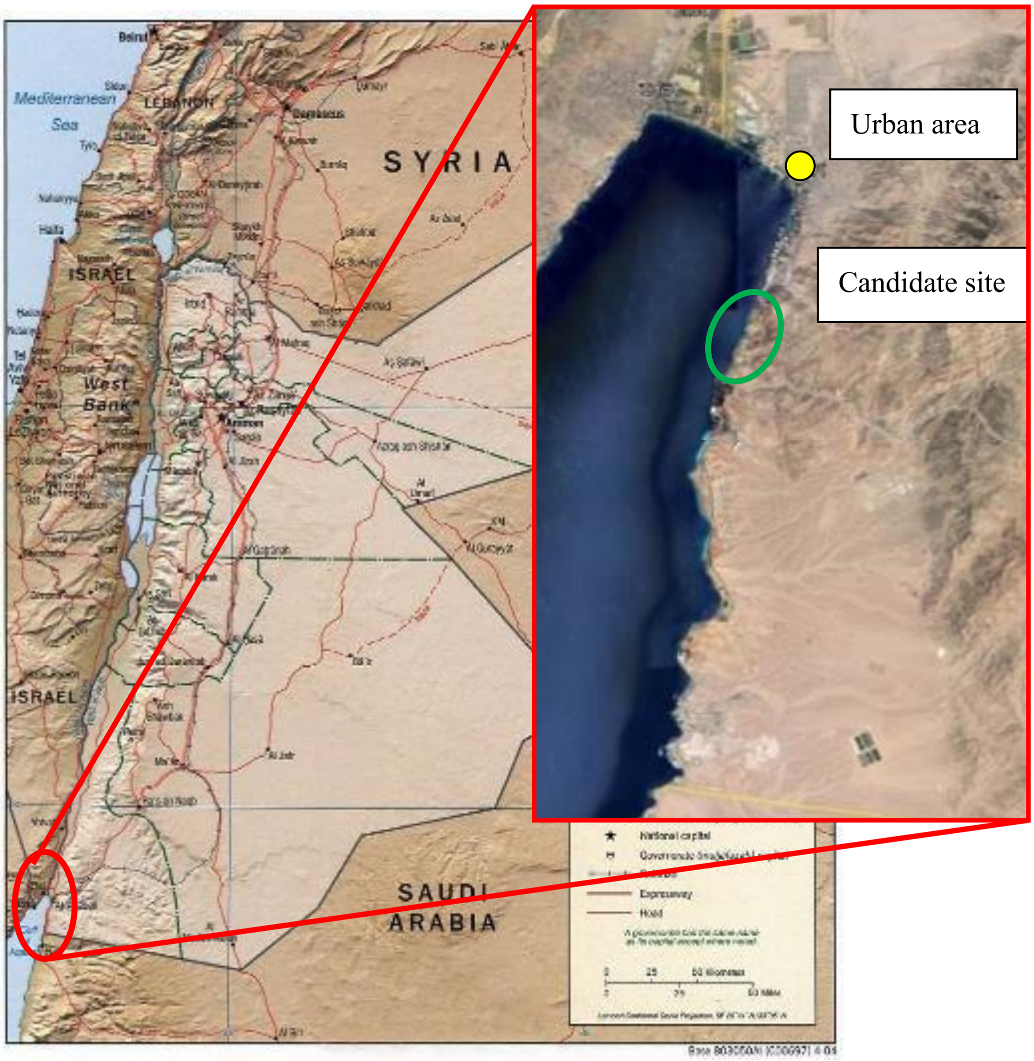
1. Existence of the coast line
2. Existence of the upper zone
   - Available the water drop to generating appropriate power
   - Located near the coast line
3. Adequate area to set output near the coast line
4. Geological condition to set penstock, power plant and other equipment in the ground

Actual Condition in Aqaba area

The lands in Aqaba area are mainly used for the residential area, commercial area, sightseeing facilities as beach, port, factory and road. Therefore, there are few candidate sites to clear above conditions in order to construct the large scale power plant the Aqaba area.

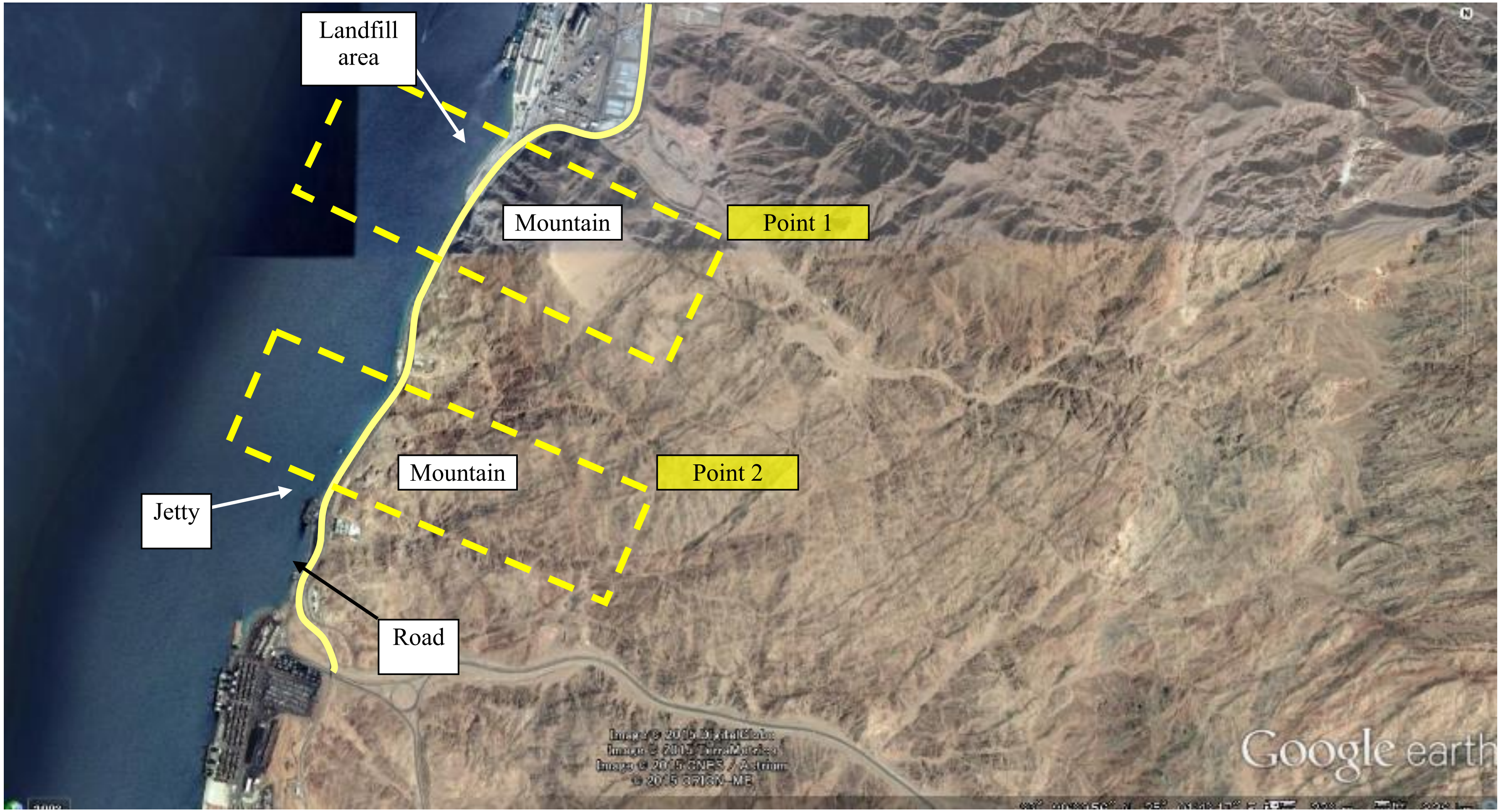
As the result of the site survey, JICA study team found the adequate area to clear the conditions; it is the 1.5 km of the coast area which locates 4 km south of the urban area. Figure 5.4-15 and Figure 5.4-16 show the actual candidate site in the area.

Main road is set around the coast side, and the north end of the coast is landfill site. On the other hand, the south end is set some jetties and anchorage of ships. JICA study team considered two (2) survey points as shown in Figure 5.4-16. There are mountains on the east side of the coast line, and the height of their ridge is high enough that they have potential to set upper rewervoir.



Source: JICA Study Team based on Google Earth

Figure 5.4-15 Brief map of candidate site for developing new pumped storage power plant



2 km

Source: JICA Study Team based on Google Earth

Figure 5.4-16 Candidate points of pumped storage power plant

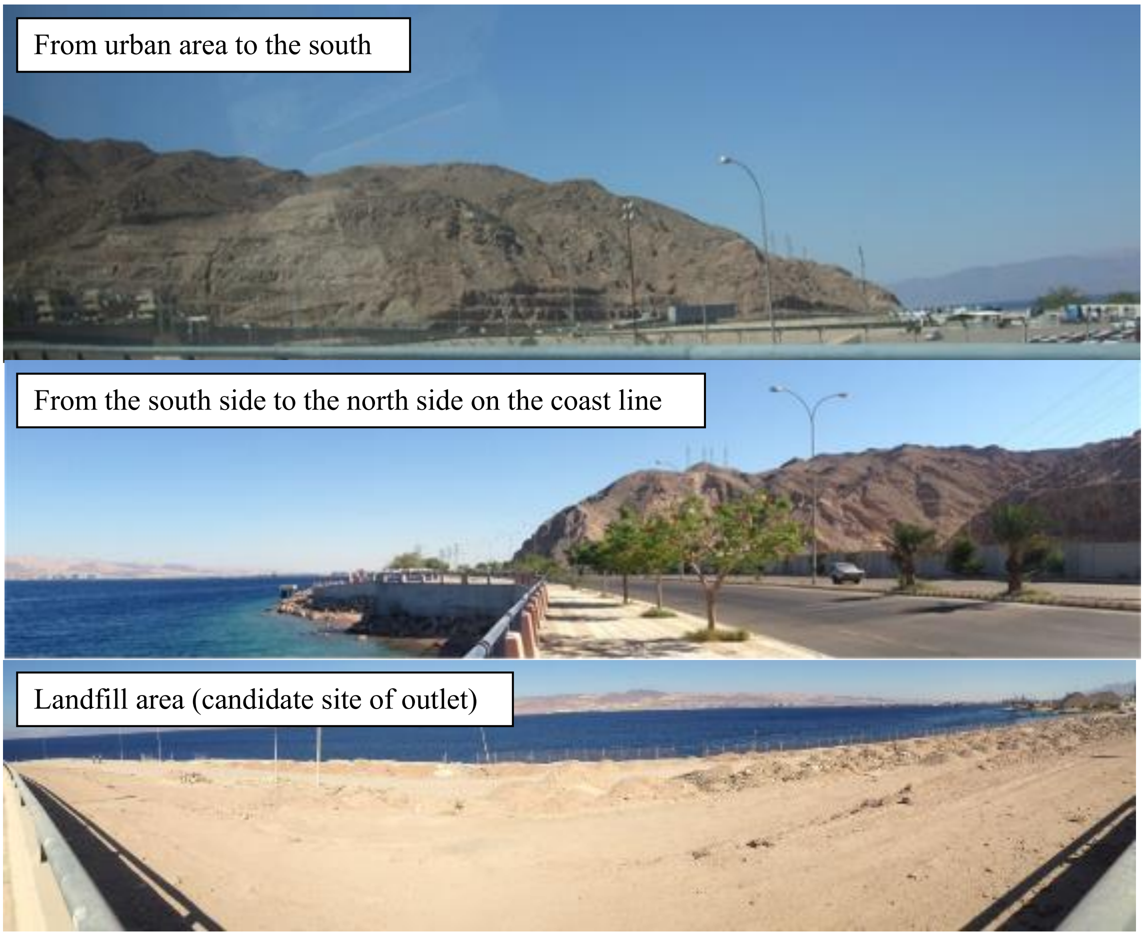
Survey Result

The result of site survey is shown as follow;

Table 5.4-11　Survey result of the candidate points

	Point 1	Point 2
Mountain area	- Cliffs are located on the immediate east of the main road - 120 ~ 140m high attitude above sea level - High altitude area is relatively wide	- Cliffs are located on the immediate east of the main road - 50 ~ 70m high attitude above sea level - High altitude area is narrow
Coast line	-Some landfill area which has potential to be widely used in the west side of the main road	- No available area in the west side of the main road

Figure 5.4-14 show pictures of the survey points.



Source: JICA Study Team

Figure 5.4-17　Pictures of the survey point 1

Consideration

1. Development area

JICA study team considered that there is no candidate site suitable for a pumped storage power plant in Aqaba area for the following reasons;

- It is possible to obtain the largest altitude above sea level in case of Phase 1 (North side) and it is expected to be developed a large scale. But the largest altitude above sea level is only about 120 to 140 m.
- The high altitude area is not so wide and it is impossible to construct the upper reservoir with large reservoir capacity.
- The landform of the candidate point is unsuitable for developing the upper reservoir.

2. Development scale

・Vertical drop : 120m ~140m

- It is possible to calculate precise value with topographic map, but it is not expected to realize large drop

・Reservior capacity : depends on the flat area in high attitude

- There is less flat area neaby coastal line so that it is necessary to take huge land development.

・Availabe capacity

- Estimated capacity is approximately 100MW at most. However, it seems to be disproportionate for investing pumped storage power plant due to costly land development.

5.4.3 Development Area of each Power Source

We considered development point of each power source in devided 5 areas as assumption; north area, central area (Amman surburb), east area (Resha and others), south area (Ma'an and others) and farthern south area (Aqaba and others).

(1) Gas fired Power Plant

Basically a gas power plant is assumed to be developed near the gas-pipeline. Candidate points of new power plant which will be developed until 2030 are shown as follows;

1) Rehab (after decommissioning of existing units which will be operated until 2016)

2) Hassna Industry

3) Near QAIA substation

New power plants after 2030 are assumed to be installed after decommissioning of exsiting power plants such as Samra Phase I and II, IPP1 and IPP2. Risha power plant has no plan to be replaced because of the small capacity of transmission line from central area.

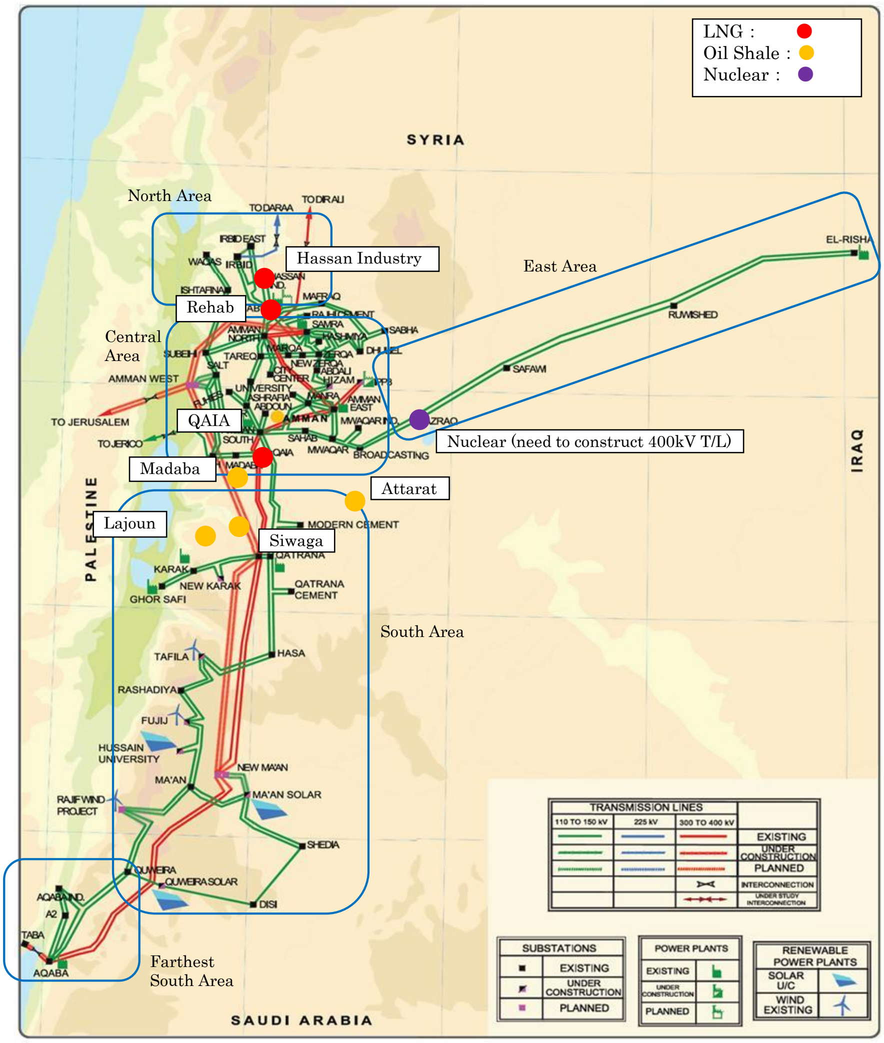
(2) Oil Shale

Siwaga and Madaba have potential to develope oil shale power plants in addition to Attarat and Lajoun. While the elements of oil shale are different in each area, 600MW ~ 900MW of new generators are estimated to be developed in each site.

(3) Nuclear

Nuclear power plant is scheduled to be developed near Azraq substation in east area. A large capacity transmission line needs to be installed in advance.

Figure 5.4-18 shows cancidate point of gas-fired, oil shale and nuclear power plant.

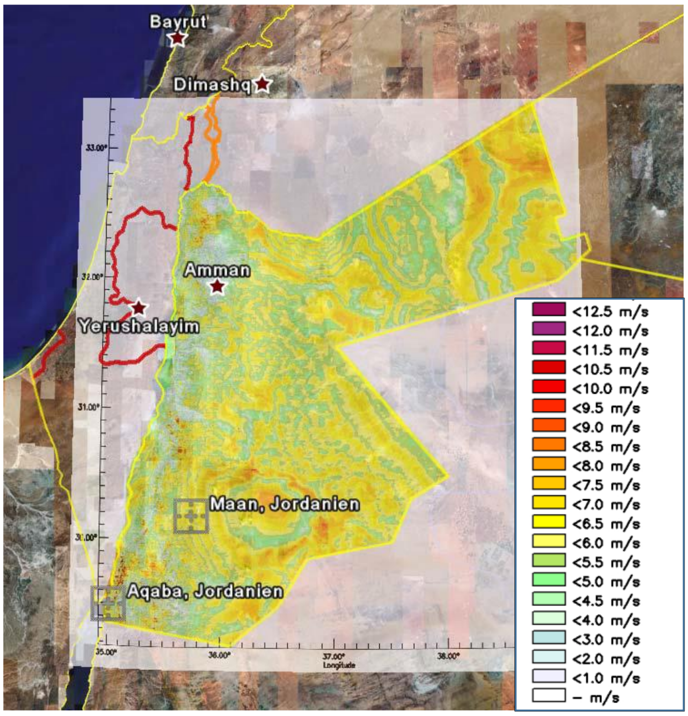


Source: JICA Study Team based on NEPCO data

Figure 5.4-18 Candidate point of gas-fired, oil shale and nuclear power plant

(4) Wind power

Figure 5.4-19 shows average annual wind speed before 2006 in Jordan. There are many potential sites to develop wind power commencing with south area.

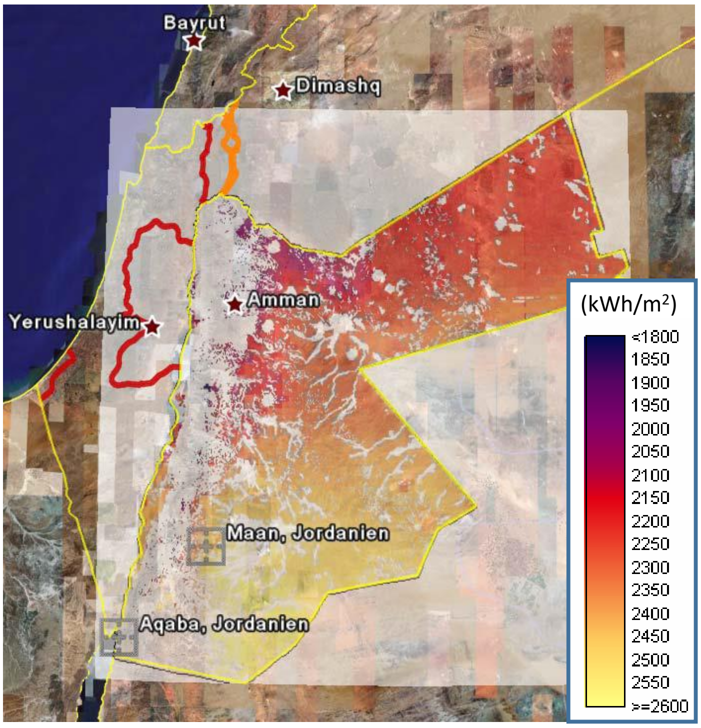


Source: MEMR "Wind and Solar Measurement and Data Collection Task 2"

Figure 5.4-19　Annual average wind speed in whole area of Jordan

(5) Solar Power

Figure 5.4-20 shows average annual sum of potential of solar power before 2006 in Jordan. There are many potencials in south area such as Ma'an.



Source: MEMR "Wind and Solar Measurement and Data Collection Task 2"

Figure 5.4-20　Average annual sum of potential of solar power in Jordan.

5.5 Installation of Renewable Energy

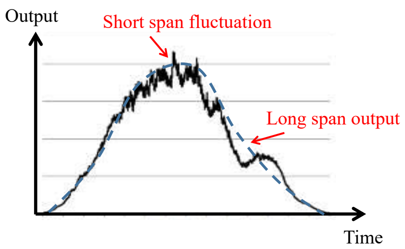
Jordan has many projects to develop large-scale wind power and solor power from 2016 to 2019. However, output of renewable energy is dependent on weather condition which changes from moment to moment, so it is difficult to forecast its output exactly and of course cannot adjust its output like a thermal power unit.

It is ideal to maintain system frequency and voltage constantly to supply electric power to customer stably. However, it entails risk to fluctuate system frequency due to unstable renewable energy output in case it is connected with large capacity into the system, and it is needed to keep reserve margin (we call operation reserve in this report) to compensate the flucutuation of renewable energy output.

In this section, we will explain characteristics of renewable energy in Jordan and calculate necessary amount of operation reserve.

5.5.1 Long span output of renewable energy

It is necessary to consider renewable energy output in the point of long span and short span which is shown in Figure 5.5-1. It is important to understand characteristics of renewable energy output in long span to make daily operation plan of other generators. Especially, solar power has a typical output curve which is related with the movement of the sun. Therefore, the larger capacity of solar power is introduced, the more significantly daily supply-demand balance operation is affected.

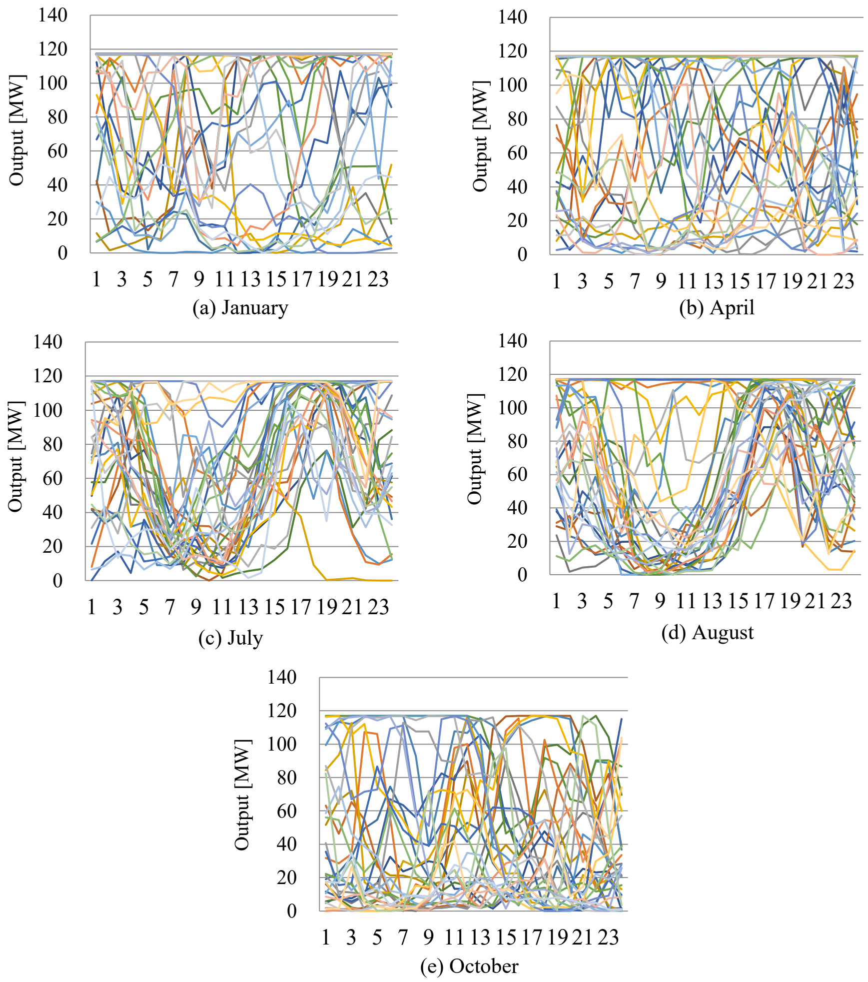


Source: JICA Study Team

Figure 5.5-1 Example of solar power output

(1) Wind speed

Figure 5.5-2 shows output curve of wind power in Tafila area in January, April, July, August and October in 2002 which is transduced from wind speed to electric power with the typical wind turbine power curve theoretically. Vertical scale is assumed the output of Tafila wind project whose maximum output is 117MW. As the wind conditions change every season, records of each day are stated in January, April, July, October and August when yearly peak demand is expected to occur in future. From Figure 5.5-2, it can be confirmed that regular winds are generated in the evening and late at night in July and August. Also, in January there were many days when the wind speed exceeding the rated output was recorded, and on the contrary it turns out that wind speed is low in October. Nonetheless, however, there are many variations in wind speed except for the summer season, so output fluctuations will be intense when wind power generation is performed, and output assumption is expected to be difficult.



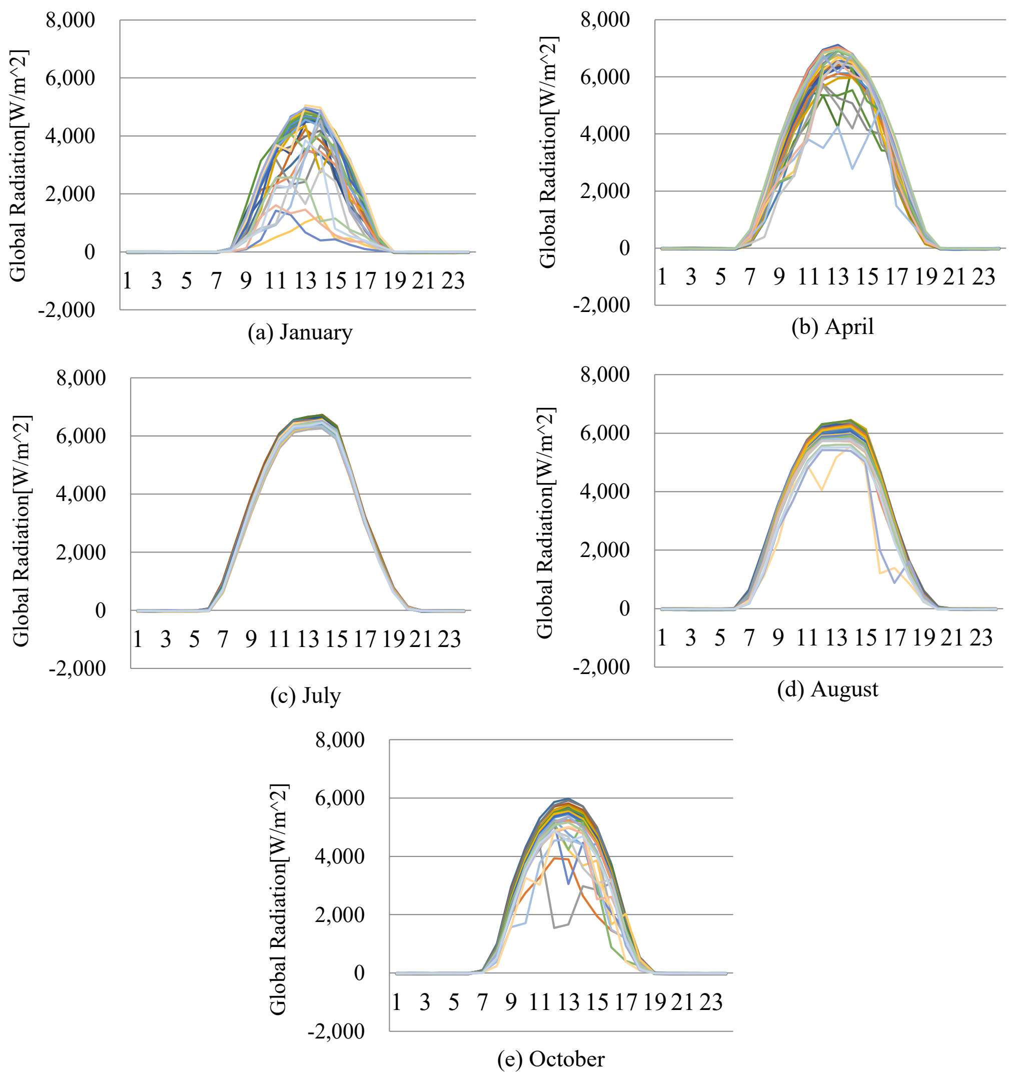
Source: JICA Study Team

Figure 5.5-2 Transduced output curve from wind speed in Tafila

(2) Solar radiation

Fig. 5.5-3 shows solar radiation data in the Ma'an area in 2008. As is the case with wind speed, as the solar radiation changes every season, records of each day are stated in January, April, July, October and August when yearly peak demand is expected to occur in future.

Although there are some changes for each season, clearer characteristics can be confirmed than the wind speed. Especially in summer, the variation is small, the amount of solar radiation is large, and the irradiation time is longer than the other seasons.

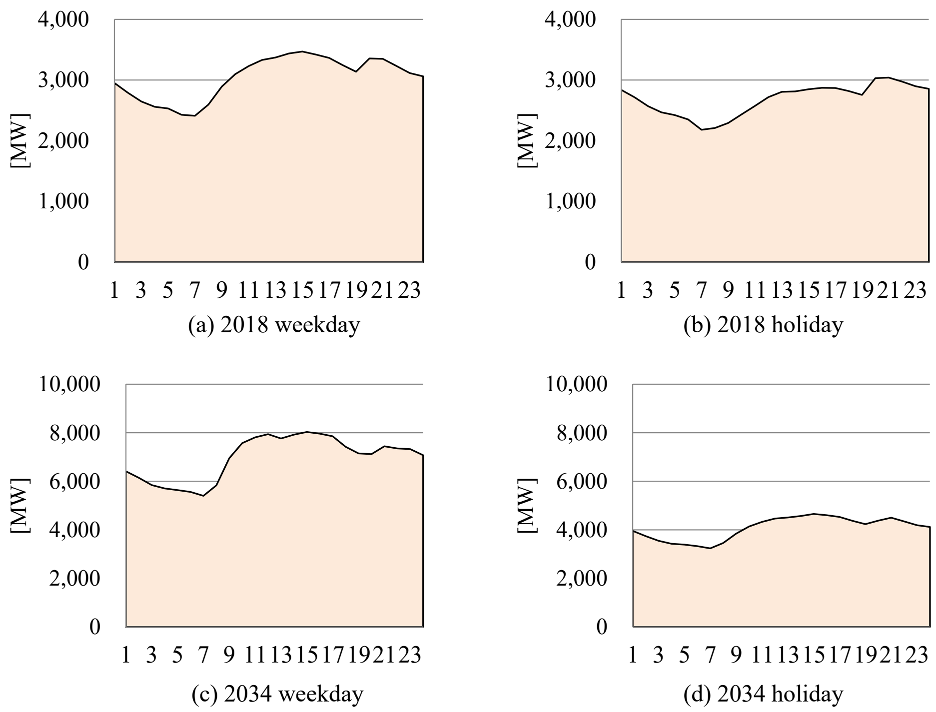


Source: JICA Study Team

Figure 5.5-3 Global radiation curve in Ma'an

(3) Daily load curve model

It is necessary to consider daily load curve (DLC) model to evaluate the characteristics of renewable energy output. In this section, JICA study team modeled DLC of weekday and holiday on January, April, July, August and October in 2018 which is assumed to be installed a lot of renewable energy into the system and in 2034 which will be the largest demand in this study period. Regarding to the DLC in 2018, JICA study team modeled it based on actual curve in 2014. Weekday in 2034 is assumed to be developed commercial and industrial demand, so JICA study team modeled DLC by reference to that in Turkey which is developed commercial and industrial and the neighbor country of Jordan. Holiday in 2034 is based on actual DLC of Holiday in 2014 because it is assumed not to operate in these sector than that on weekday. As an example, Figure 5.5-4 shows each DLC on August.

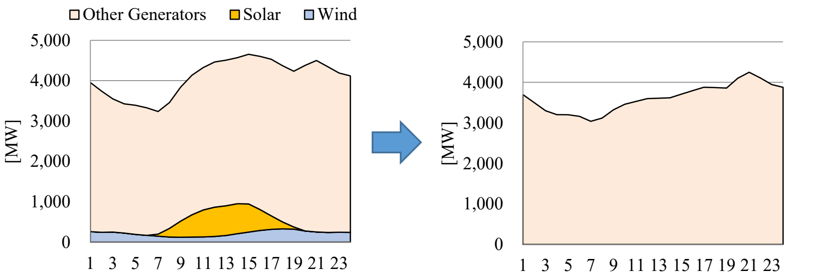


Source: JICA Study Team

Figure 5.5-4 DLC model in August in 2018 and 2034

(4) Evaluation of renewable energy output in DLC

Using above data, JICA study team evaluated the installation of renewable energy output in 2018 and 2034 in each season. In the concrete, JICA study team simulated daily load which is necessary to be suppled by other generators by deducting renewable energy output from DLC model as Figure 5.5-5. Output curve of wind power and solar power is used average data of daily output curves in each month. Installed capacity of renewable energy until 2020 is used each project data. Installed capacity of renewable energy after 2020 is assumed to be developed 20% of peak demand and the ratio of wind to solar is set as 1 to 3.

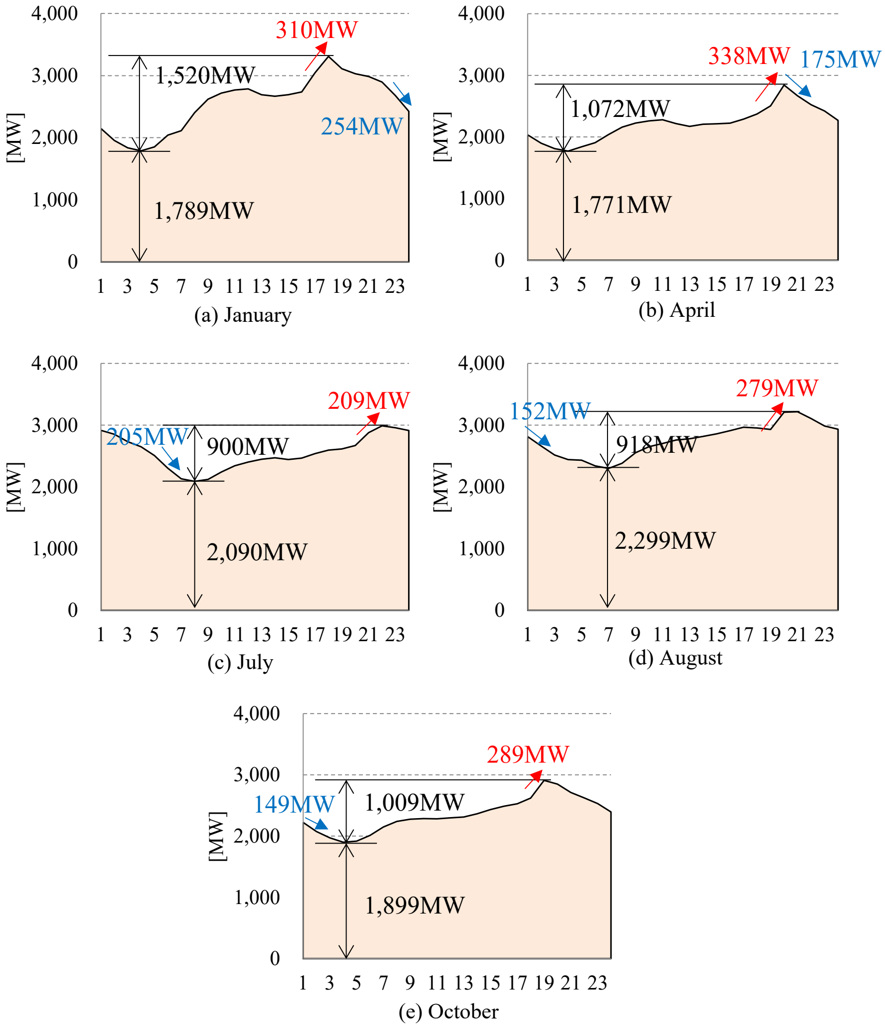


Source: JICA Study Team

Figure 5.5-5 Simulation model (Evaluation of renewable energy output)

As an example, Figure 5.5-6 shows DLC of weekday deducted renewable energy output in each season in 2018. Red arrow in these figures shows the highest necessary amount of increase by one hour with other generator in a day and blue arrow shows the highest necessary amount of decrease. Lower number with black color is the lowest output by other generators and upper number is the difference between highest output and lowest output in a day.

From this, it can be seen that in the time zone in which the output change amount is the largest in one day, the increase is due to lighting demand and the decrease is the late-night zone. Since the lighting start time is late in summer, it does not coincide with the output reduction time of solar output, the short-time power adjustment amount by thermal power plant etc. is less than other seasons. In seasons other than summer season, as the lighting demand increases and the timing at which output of solar output coincides with each other coincide, a large amount of adjustment is required. Also, the difference between maximum power and minimum power is about 1,500 MW, and the reason why the largest amount of adjustment is required in winter is that the heating demand is high but the solar output amount is small.



Source: JICA Study Team

Figure 5.5-6 DLC of weekday deducted renewable energy output in 2018

Based on the above-mentioned characteristics, JICA study team also simulated DLC of the holidays in 2018 and weekdays/holidays in 2034 by deducting the renewable energy output in the same way as on the weekday of 2018. Table 5.5-1 shows the results of the simulation. It can be seen that in all cases the output of thermal power generators is maximized when lighting demand occurs, whereas the output is minimized in early morning when solar output is small. Also, it can be seen that the maximum power adjustment amount per hour on weekends of 2034 is more than the year 2018. Since this sudden demand change is the morning launch demand, solar output works to reduce the power adjustment amount by thermal power generators in the morning. However more power adjustment amount per hour of weekdays/holidays in 2018 and holidays in 2034 (excluding the summer) is required because solar output decreases whereas lighting demand increases.

From a viewpoint of economic efficiency, it is desirable that the generator output be constant throughout the day. In order to reduce the difference between peak output and off-peak output in a day, it is necessary to install the battery and take measures for load leveling. In addition, the monthly wind power generation and solar power generation curve model used in this study are prepared by averaging the daily wind speed and solar radiation amount data shown in Figure 5.5-2 and Figure 5.5-3. For this reason, it is necessary to separately evaluate the influence of wind power generation whose output sharply fluctuates on supply-demand balance operation, and for that purpose, more detailed analysis such as using plural data measured in different locations in different area is required.

Table 5.5-1 Characteristics of DLC of weekday model and holiday model in 2018 and 2034

(a) Weekday, 2018

	Maximum		Minimum		Difference	Up		Down	
	Capacity	Time	Capacity	Time		Capacity	Time	Capacity	Time
	(MW)	(hour)	(MW)	(hour)	(MW)	(MW)	(hour)	(MW)	(hour)
January	3,309	18	1,789	4	1,520	310	16-17	254	23-24
April	2,843	20	1,771	4	1,072	338	19-20	175	20-21
July	2,989	22	2,090	8	899	209	20-21	205	5-6
August	3,217	21	2,299	7	918	279	19-20	152	1-2
October	2,909	19	1,899	4	1,010	289	18-19	149	1-2

(b) Friday, 2018

	Maximum		Minimum		Difference	Up		Down	
	Capacity	Time	Capacity	Time		Capacity	Time	Capacity	Time
	(MW)	(hour)	(MW)	(hour)	(MW)	(MW)	(hour)	(MW)	(hour)
January	2,929	18	1,746	4	1,183	308	16-17	208	23-24
April	2,521	20	1,660	8	861	389	19-20	147	1-2
July	2,852	22	1,749	10	1,103	217	20-21	240	5-6
August	2,908	21	1,954	9	954	337	19-20	195	6-7
October	2,609	20	1,803	7	806	264	18-19	145	1-2

(c) Weekday, 2034

	Maximum		Minimum		Difference	Up		Down	
	Capacity	Time	Capacity	Time		Capacity	Time	Capacity	Time
	(MW)	(hour)	(MW)	(hour)	(MW)	(MW)	(hour)	(MW)	(hour)
January	7,049	18	4,761	6	2,288	736	8-9	336	1-2
April	6,455	21	4,577	7	1,878	606	8-9	350	23-24
July	6,766	23	4,893	7	1,873	666	8-9	313	1-2
August	7,228	21	5,220	7	2,008	919	8-9	304	2-3
October	6,680	19	4,830	5	1,850	531	8-9	425	12-13

(d) Friday, 2034

	Maximum		Minimum		Difference	Up		Down	
	Capacity	Time	Capacity	Time		Capacity	Time	Capacity	Time
	(MW)	(hour)	(MW)	(hour)	(MW)	(MW)	(hour)	(MW)	(hour)
January	4,529	18	2,766	4	1,763	461	17-18	325	23-24
April	3,880	20	2,560	8	1,320	585	19-20	227	1-2
July	3,545	22	2,043	11	1,502	285	20-21	251	5-6
August	4,286	21	3,055	7	1,231	242	19-20	199	2-3
October	3,864	20	2,671	9	1,193	340	18-19	214	1-2

Source: JICA Study Team

5.5.2 Short span fluctuation of renewable energy

Renewable energy output fluctuates in short span in line with the temporary change of weather condition such as a moving of cloud and a change of wind direction. Development site of renewable energy in Jordan is concentrated in south area, and it is supposed to change its output at the same time. It means that large fluctuation of renewable energy output causes the large flucutuation of system frequency. So it is necessary to keep operation reserve to compensate the fluctuation everytime.

(1) System frequency characteristics constant

It is necessary to simulate the characteristic of the system to evaluate the influence of the short span fluctuation of renewable energy. In this study, system frequency characteristics constant K is calculated with the formula shown as follows;

$$K = \frac{\Delta p / p}{\Delta f} [\%MW / Hz]$$

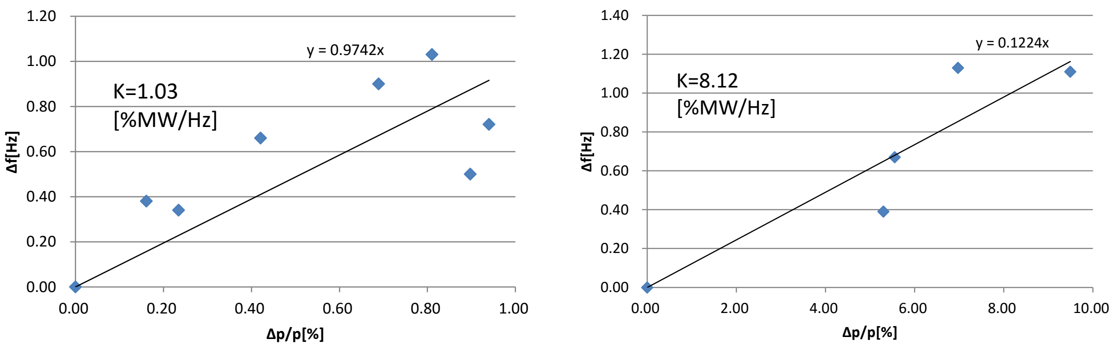
Δp: Unit capacity of tripped generator [MW]

p: System capacity [MW]

Δf: maximum frequency drop at outage [MW]

Constant K is the index of system stability and shows the degree of the outage of generators in case system frequency is dropped 1Hz. Actual accident data of generator drop from the system to calculate the constant K is collectecd from National Control Center (NCC) in NEPCO.

Figure 5.5-7 shows simulation result with actual system accident data in Jordan to calculate the constant K. Figure (a) shows the characteristics in case Jordan system is connected with Egypt system before each accident, and figure (b) shows disconnected with Egypt system. From these results, constant K in case (a) is calculated as 1.03 %MW/Hz and in case (b) is calculated as 8.12 %MW/Hz. In this simulation, Egypt system capacity is assumed to be 10 times of Jordan system capacity.



(a) Connected with Egypt System (b) Disconnected with Egypt System

Source: JICA Study Team

Figure 5.5-7 System frequency characteristics constant K

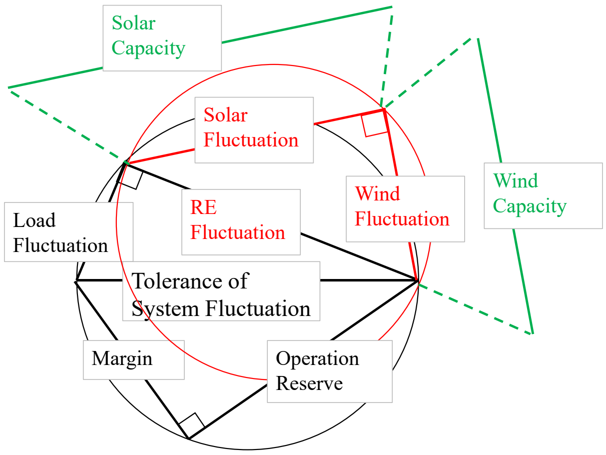
This result enables not only calculating a limit of the fluctuation of renewable energy but also acceptable capacity of a new generator in the point of system frequency.

It is necessary to simulate it in more detail taking into consideration several aspects such as inertia of the system and influence of load shedding, and it is also necessary to collect more actual data to make the constant K more reliable.

(2) Evaluation method

Algebraic method which is shown in Figure 5.5-8 is used in this study to evaluate the characteristic of short span fluctuation of renewable energy. This is simplified method the relationship between the system fluctuation by demand and renewable energy output and the absorption of its fluctuation, and this method is generally used in Japan.

Using this method, evaluation of short span fluctuation in every 10 minutes is conducted and finally calculated amount of operating reserve to compensate the fluctuation of renewable energy. Installed capacity of renewable energy after 2020 is assumed to be developed 20% of peak demand and the ratio of wind to solar is set as 1 to 3.



Source: JICA Study Team

Figure 5.5-8 Algebraic method

(3) Simulation result

Table 5.5-2 shows the simulation result. Operating reserve will be needed about 230MW in 2019 and needed 300MW in 2034. This result means that it has possibility to change 300MW of renewable energy fluctuation within 10 minutes, and also means that it will be needed to keep thermal unit stand-by operation or install battery into the system.

Table 5.5-2 Simulation result to calculate operating reserve

[MW]

Year	Peak Demand	Wind cumulative	Solar cumulative	RE total	Operating Reserve
2015	3,300	117		117	75
2016	3,493	197	204	401	92
2017	3,633	197	279	476	100
2018	3,801	369	680	1,049	159
2019	3,981	614	1,080	1,694	236
2020	4,164	614	1,080	1,694	237
2021	4,358	614	1,080	1,694	239
2022	4,563	614	1,080	1,694	241
2023	4,773	614	1,080	1,694	243
2024	4,999	614	1,080	1,694	245
2025	5,239	614	1,080	1,694	247
2026	5,487	614	1,080	1,694	250
2027	5,751	614	1,080	1,694	252
2028	6,030	614	1,080	1,694	255
2029	6,323	614	1,080	1,694	259
2030	6,633	614	1,080	1,694	262
2031	6,957	614	1,080	1,694	266
2032	7,299	614	1,095	1,709	272
2033	7,654	614	1,148	1,762	283
2034	8,032	614	1,205	1,819	294

Source: JICA Study Team

5.6 WASP-IV Simulation

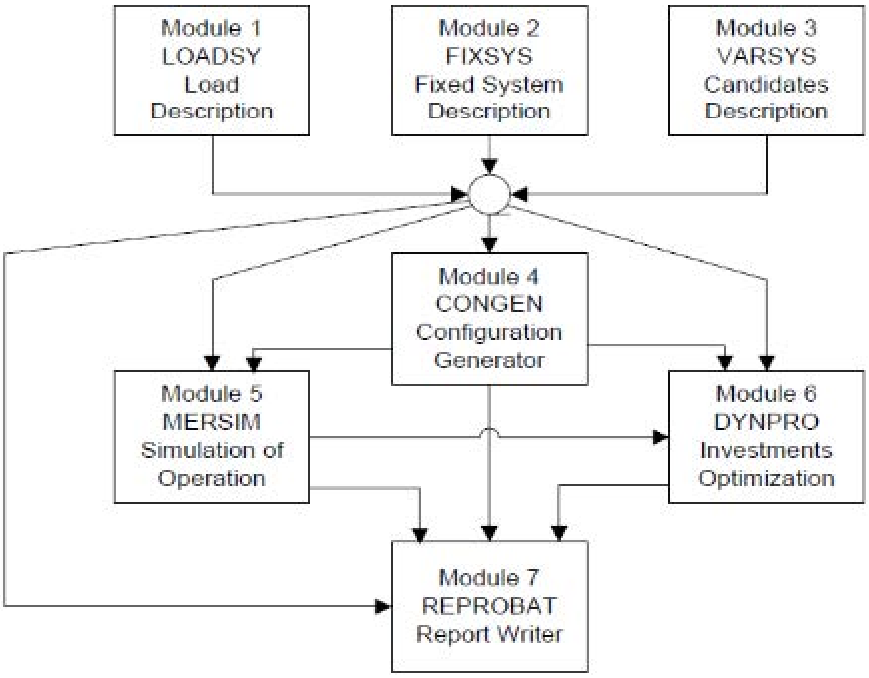
5.6.1 About WASP-IV

The generation development plan for the Study will be formulated using the WASP-IV simulation tool. The procedure of simulation using WASP-IV and the features of this kind of simulation are described in this section.

(1) Outline

WASP-IV consists of seven (7) modules to simulate generation expansion with minimum cost through the setting period. Figure 5.6-1 shows the flowchart of WASP-IV simulation.

WASP-IV can simulate to set threshold of the amount of fuel supply and pollutant emission like CO_2 and NO_x. And more, it can simulate the characteristic of renewable unit and also easily simulate accommodation of electric power with another country by setting as thermal unit.



Source: Energy Institute "Hrvoje Požar"

Figure 5.6-1 Flowchart of WASP-IV simulation

(2) Objective Function

Simulations using WASP-IV seek to minimize costs as the expense of reliability. An objective function for that purpose is configured. The costs that make up the objective function include capital costs, fuel costs and O&M costs. In addition to these, the cost corresponding to energy that is not supplied (unserved energy cost) is also taken into consideration. The write-off of capital costs is taken into account by including the salvage value according to the remaining depreciation period as part of the objective function.

$$B_j = \sum_{i=1}^{T} (I_{j,t} - S_{j,t} + F_{j,t} + L_{j,t} + M_{j,t} + O_{j,t})$$

t = time, t= 1,..., T
$I_{j,t}$ = Capital costs
$S_{j,t}$ = Salvage value
$F_{j,t}$ = Fuel costs
$L_{j,t}$ = Fuel inventory costs
$M_{j,t}$ = O&M costs
$O_{j,t}$ = Unserved energy costs

(3) Power Demand

In the internal workings of WASP-IV, power demand is not a load curve arranged as a time series. Rather, it is expressed as a load duration curve. This load duration curve, together with the envisioned demand, yields the maximum annual demand. The use of this quantity expresses the load characteristic within WASP-IV. In order to simulate the detailed load characteristic, the year is divided into a maximum of 12 periods, each of which can be given a load duration curve and maximum demand.

(4) Generator Operating Characteristics

WASP-IV can deal with a number of different types of power plants, including hydropower, thermal power and nuclear power. The operating characteristics of thermal power plant can be modeled for each generator unit by taking into account cost characteristics such as heat rate, the heating value and the O&M costs (fixed costs and variable costs), as well as anticipated parameters such as forced outage rate, spinning reserve and the maintenance days.

Meanwhile, it is possible to model the stochastic generation characteristic of a hydropower plants by taking into account the seasonal fluctuation in water flow, the average generation capacity and the available generation energy. These data can also be configured to model the operating patterns of different types of generator, such as the run-off river type and the reservoir type.

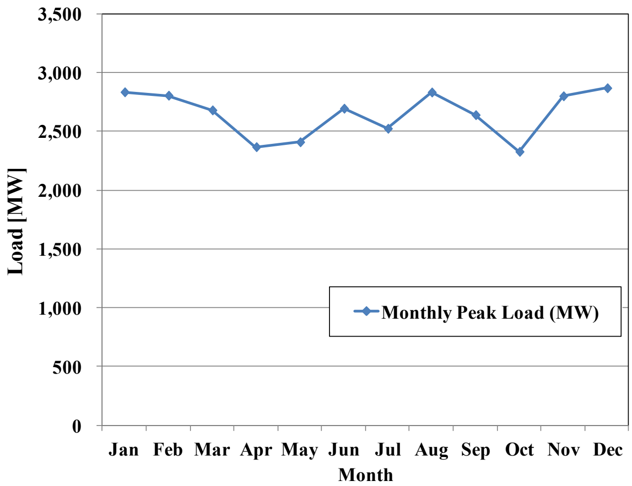
(5) Optimization Calculations

The variable costs of an existing or candidate generator unit can be calculated using the above power demand characteristic and the operating characteristic of the generator unit. By operating generator with lower-cost first, the simulation can be made to approach actual operating conditions quite closely.

Furthermore, the capital cost of a new generator unit can be added in and the objective function described above can be minimized. This will automatically derive sequence of generation development, which shows the minimum cost during the study period.

5.6.2 Characteristics of Power Demand in Jordan

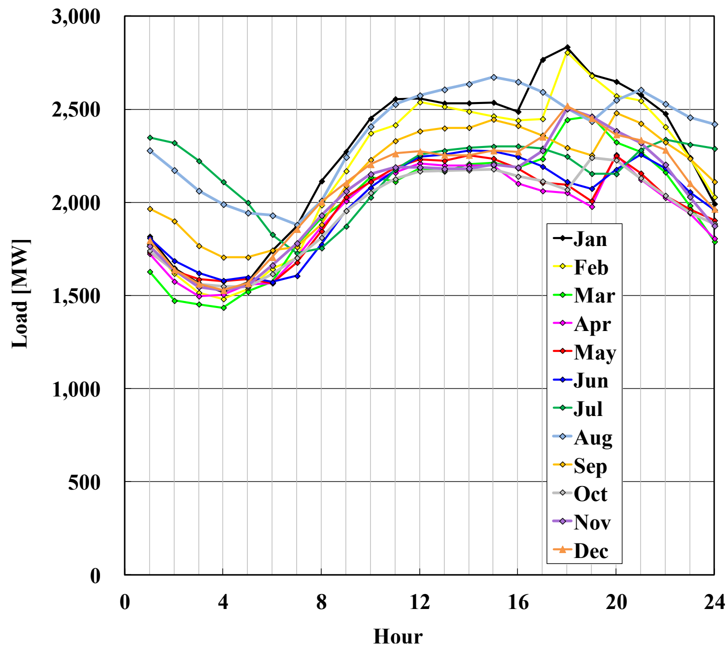
Figure 5.6-2 shows monthly peak load in 2014. Through the year, peak demand in each month is recorded around 2,600MW and yearly peak is recorded 2,900MW in December. Summer and winter recorded heavier load than spring and autumn because of the demand for air conditioners.



Source: JICA Study Team

Figure 5.6-2 Monthly Peak Load in 2014

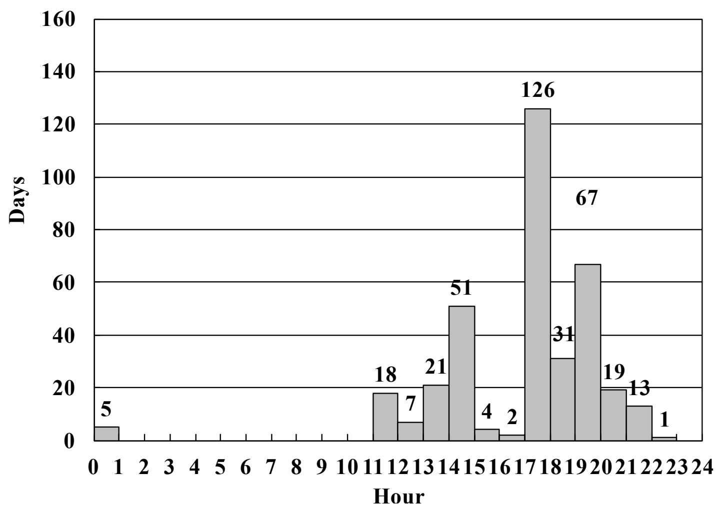
Figure 5.6-3 shows Typical Daily Load Curve in 2014. It means that peak load occurs at evening except summer season. It will be supposed that the demand for lighting is the main source to record the daily peak. Especially, demand for lighting and air conditioner will be lapped in winter season. On the other hand, daily peak load occurs around 3 pm in summer season. Moreover, it will be supposed that air conditioner is used not only daytime but also midnight in summer season.



Source: JICA Study Team

Figure 5.6-3 Typical Daily Load Curve in 2014

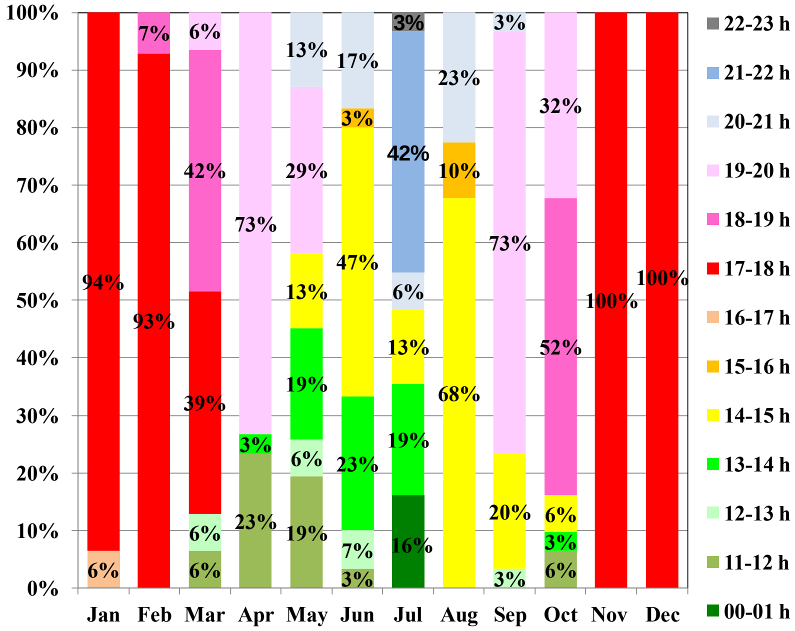
Figure 5.6-4 shows occurrence hour of daily peak load in 2014. Two thirds of the year, daily peak load had recorded during 5pm ~ 8pm. It will be supposed that it records mainly on lighting time, and on the time which air conditioner is used especially on summer season at 3 pm.



Source: JICA Study Team

Figure 5.6-4 Occurrence Hour of Daily Peak Load in 2014

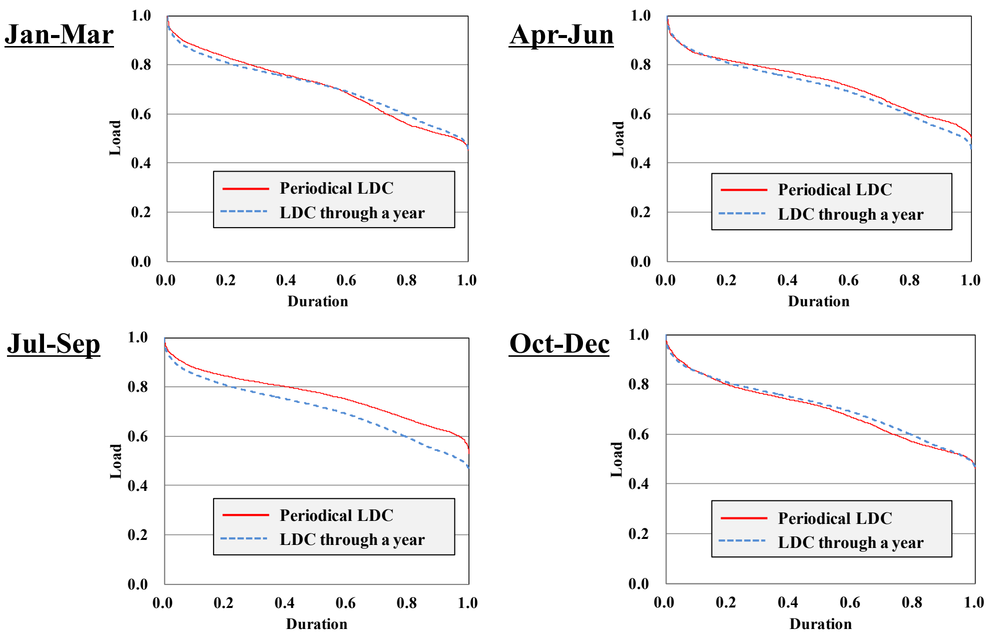
Figure 5.6-5 shows composition of occurrence hour of daily peak load in 2014. In winter season, daily peak load occurs at evening almost all because lightning and air condition are started in this time. On the other hand, in summer season it occurs at daytime because of air conditioner, and in spring and autumn season it occurs at evening because of lighting.



Source: JICA Study Team

Figure 5.6-5 Composition of Occurrence Hour of Daily Peak Load in 2014

Figure 5.6-6 shows periodical load duration curves (hereinafter referred to as “LDC”) in 2014. LDC on summer season is more flat than other seasons because of the usage of the power not only daytime but also midnight time.



Source: JICA Study Team

Figure 5.6-6 Periodical Load Duration Curves in 2014

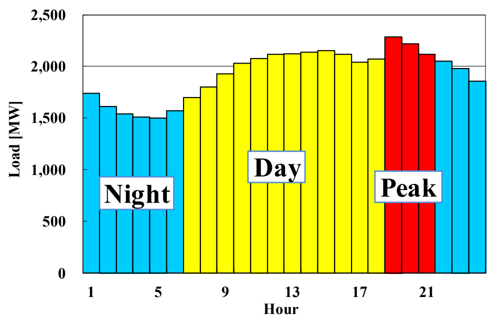
Figure 5.6-7 shows load distribution on LDC by time zone in 2014. In the Study accurate simulation characteristics for the demand occurrence shown in the above figures was examined by using actual demand in 2014. In the examination the demand was categorized by occurrence hour and the distribution of demand by each of the time zones shown below was checked.

1) Midnight-time 9 pm - 6 am
2) Daytime 6 am - 6 pm
3) Peak-time 6 pm - 9 pm

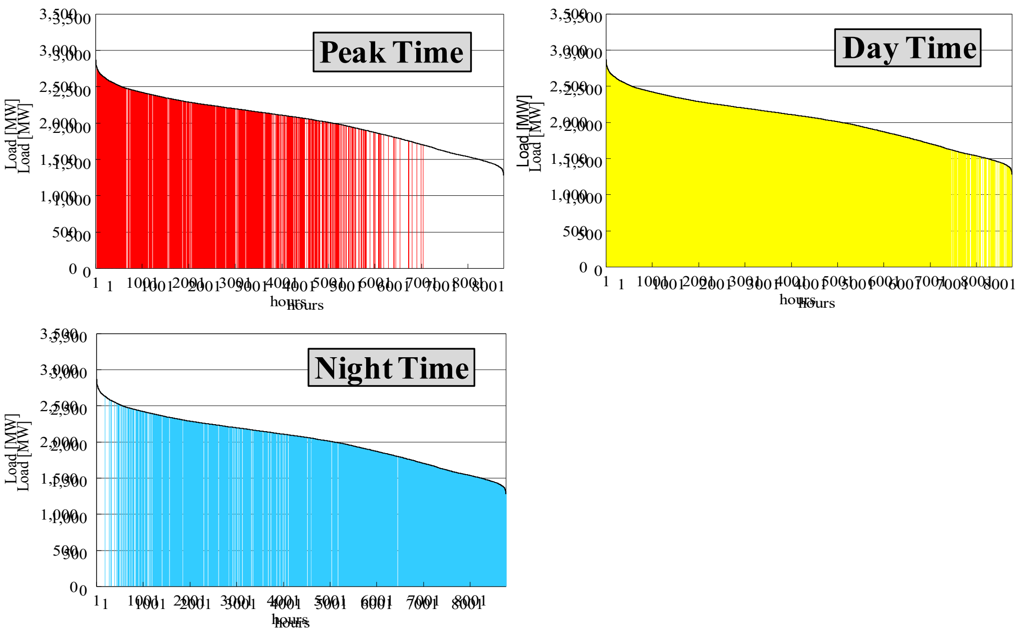
The demand for each time zone is clearly distributed on the load duration curve especially in winter season. This means that the actual demand that occurred chronologically is faithfully simulated on the load duration curve.

Consequently, simulation will be able to consider the actual pattern of demand occurrence with sufficient accuracy.

Time Zone



LDC (Through the year)



Source: JICA Study Team

Figure 5.6-7 Load Distribution on LDC by time zone in 2014

5.6.3 Data of Existing Power Plants

Table 5.6-1 and Table 5.6-2 show the specification data of existing power plants in Jordan for WASP-IV simulation. In this data, wind energy is set in FIXSYS module of WASP-IV and devided unit number to adapt specification on WASP-IV (to be discussed). Solar energy is not set in FIXSYS module but describe as subtracting from LDC (to be discussed).

Table 5.6-1 Specifications of Generation Units of Existing Thermal Power Plants

No.	Plant Name	Fuel	Type	No. of Unit (2015)	Min. operating level in each year (MW)	Max. generating capacity in each year (MW)	Heat rate at mim. operating level (kcal/kWh)	Heat rate at max. operating level (kcal/kWh)	Avg. incremental heat rate (kcal/kWh)	Forced outage rate (%)	Scheduled maintenance days per year (day)	Maintenance class size (MW)	Domestic fuel cost at 2015 (c/M-kcal)	Foreign fuel cost at 2015 (c/M-kcal)	Fixed O&M cost at 2015 ($/kW-month)	Variable O&M cost at 2015 ($/MWh)
1	ATPS	3	LNG	5	55	121	2,795	2,755	2,722	3	30	121	0	3,334	0.0	0.7
2	HTPS	0	HFO	3	28	48	3,385	3,346	3,291	5	30	48	0	3,881	0.0	0.4
3	Risha	2	NG	5	6	25	4,607	4,256	4,145	5	15	25	800	0	0.0	1.2
4	RehabGT	3	LNG	2	6	26	4,607	4,251	4,145	5	15	26	0	3,334	0.0	3.1
5	RehabCC	3	LNG	1	180	260	2,503	2,438	2,290	2	30	260	0	3,334	0.0	3.1
6	Amman South	3	LNG	1	6	26	4,607	4,251	4,145	5	15	26	0	3,334	0.0	3.0
7	SAMRA1	3	LNG	1	180	270	2,520	2,448	2,303	2	30	270	0	3,334	1.0	0.2
8	SAMRA2	3	LNG	1	180	270	2,520	2,448	2,303	2	30	270	0	3,334	1.0	0.2
9	SAMRA3	3	LNG	1	200	400	2,520	2,411	2,303	2	30	400	0	3,334	1.0	3.0
10	SAMRAGT7	3	LNG	1	130	145	3,564	3,527	3,207	5	15	145	0	3,334	0.6	0.2
11	SAMRA4	3	LNG	0	160	220	2,520	2,461	2,303	2	30	220	0	3,334	0.6	0.2
12	IPP1	3	LNG	1	270	360	2,424	2,370	2,206	2	30	360	0	3,334	2.7	0.1
13	IPP2	3	LNG	1	270	360	2,340	2,287	2,130	2	30	360	0	3,334	2.6	0.4
14	IPP3	3	LNG	38	15.46	15.46	2,195	2,195	1,978	5	15	15	0	3,334	3.5	10.0
15	IPP4	3	LNG	16	15.46	15.46	2,037	2,037	1,990	5	15	15	0	3,334	2.1	10.0
16	ACWA	3	LNG	0	315	485	1,845	1,845	1,845	4	30	485	0	3,334	0.2	0.8
17	Attarat	6	OilS	0	180	235	2,687	2,525	1,996	5	35	235	457	0	28.9	0.0
18	WJT	7	Wind	0	1.65	1.65	3,000	3,000	3,000	62	0	0.0	0	0	0.0	119.9
19	WKHU	7	Wind	0	4.00	4.00	3,000	3,000	3,000	75	0	0.0	0	0	0.0	112.8
20	WFuj	7	Wind	0	1.65	1.65	3,000	3,000	3,000	70	0	0.0	0	0	0.0	112.8
21	WGWR	7	Wind	0	1.05	1.05	3,000	3,000	3,000	63	0	0.0	0	0	0.0	112.8
22	WKOS	7	Wind	0	2.50	2.50	3,000	3,000	3,000	61	0	0.0	0	0	0.0	112.8
23	WXen	7	Wind	0	1.65	1.65	3,000	3,000	3,000	64	0	0.0	0	0	0.0	112.8
24	WHec	7	Wind	0	1.60	1.60	3,000	3,000	3,000	75	0	0.0	0	0	0.0	112.8
25	WMas	7	Wind	0	5.00	5.00	3,000	3,000	3,000	75	0	0.0	0	0	0.0	105.8

Source: JICA Study Team

Table 5.6-2 Operational Plan of Existing Thermal Power Plants

Thermal Plant Name	No. of Unit (2015)	Increment No. of Unit																			
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
ATPS	5						-2											-3			
HTPS	3		-3																		
Risha	5		-1	-3														-1			
RehabGT	2				-1		-1														
RehabCC	1												-1								
Amman South	1			-1																	
SAMRA1	1																				-1
SAMRA2	1																				
SAMRA3	1																				
SAMRAGT7	1				-1																
SAMRA4	0				1																
IPP1	1																				
IPP2	1																				
IPP3	38																				
IPP4	16																				
ACWA	0				1																
Attarat	0					2															
WJT	0	76																			
WKHU	0		20																		
WFuj	0				54																
WGWR	0				82																
WKOS	0					20															
WXen	0					30															
WHec	0					28															
WMas	0					20															

Source: JICA Study Team

5.6.4 Data of Candidate Power Plants

Table 5.6-3 shows the specification data of candidate power plants for WASP-IV simulation. For future generator in Jordan, oil shale and nuclear power plant are added as a new source.

Table 5.6-3 Specifications of Candidate Power Plants

No.	Plant Name	Fuel Type		Installed Capacity (MW)	Plant Use Ratio (%)	Sent Out Min.Ope. Cap. (MW)	Sent Out Max. Ope Cap. (MW)	Construction Cost (USD/kW)	Plant Life (Year)	Construction Period (year)
1	G15o	1	DO	150	3.0	73	146	550	25	1.5
2	G15g	3	LNG	150	3.0	73	146	550	25	1.5
3	CC45	3	LNG	450	4.0	216	432	800	25	2.5
4	S30g	3	LNG	300	4.0	202	288	1,300	30	3.0
5	OSH	6	OilS	300	7.7	249	277	4,700	30	4.0
6	NPP	4	Nuc	1000	6.0	799	940	6,000	60	5.0
7	COAL	5	Coal	600	8.0	469	552	2,100	30	4.0

No.	Plant Name	Heat rate at Max. Ope. Cap (kcal/kWh)	Heat rate at Min. Ope. Cap (kcal/kWh)	Heat Rate Ave. Incre. (kCal/kWh)	Forced outage rate (%)	Scheduled maintenance days per year (day)	Maintenance class size (MW)	Domestic fuel cost at 2015 (c/M-kcal)	Foreign fuel cost at 2015 (c/M-kcal)	Fixed O&M cost at 2015 ($/kW-month)	Variable O&M cost at 2015 ($/MWh)
1	G15o	2,606	2,912	2,300	3.0	15	146	0	6,546	0.5	3.0
2	G15g	2,606	2,912	2,300	3.0	15	146	0	3,334	0.5	3.0
3	CC45	1,792	2,233	1,350	3.0	30	432	0	3,334	0.4	2.4
4	S30g	2,293	2,355	2,150	4.0	30	288	0	3,334	0.6	2.2
5	OSH	2,619	2,688	1,996	5.0	30	277	441	0	28.9	0.0
6	NPP	2,690	2,690	2,690	1.5	21	940	0	484	5.6	4.5
7	COAL	2,263	2,312	2,150	5.0	35	552	0	1,336	0.6	2.3

Source: JICA Study Team

5.6.5 Fuel Price Scenario

Considering Jordan's fuel supply system at present, NEPCO draws up an electric power supply plan that includes various type of primary energy as fuels. The fuel price scenario for future generation development in Jordan is described in this section.

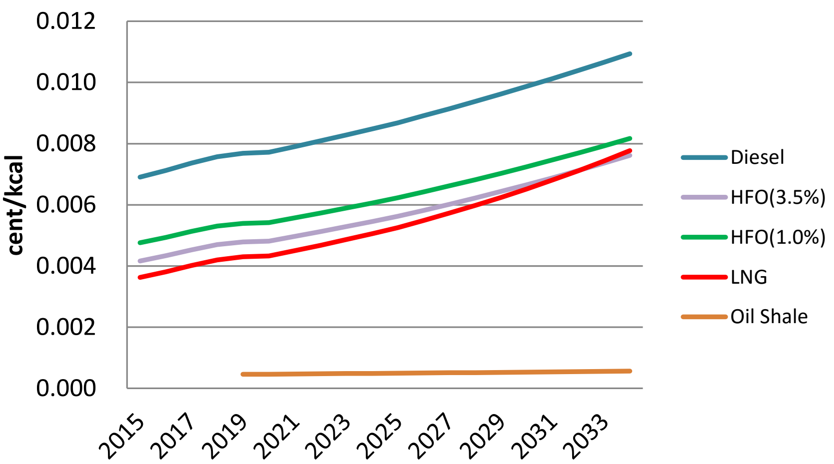
Table 5.6-4 shows fuel supply scenario in Jordan. NG imported from Egypt is not put as supplied fuel considering present state. On the other hand, NG imported from Mediterranean countries are set to be introduced 500MMSCFD from 2021. LNG from FSRU will be supplied through the period by implementing recontract after the finish of present supply. The starting year of fuel for oil shale and nuclear power plants are set as operational year drawn up by NEPCO, and that of coal is set considering to be started construction plan from 2016.

Table 5.6-4　Fuel Supply Scenario in Jordan

Fuel	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24	'25		'34
Diesel Oil					Unlimited								
Heavy Fuel Oil					Unlimited								
NG from Egypt					Not Dependable								
NG from Mediterranean								Uncertain					
LNG from FSRU		500MMSCFD(until 2025) and additional cap.(on and after 2026)											
Oil Shale						Unlimited							
Nuclear									Available for 2,000MW				

Source: JICA Study Team

The calculation method of diesel, HFO, LNG and oil shale through the period. Figure 5.6-8 shows Fuel Price Scenario in Jordan. It can be seen that diesel price is the highest of all the fuel. On the other hand, oil shale is the lowest price through the period.



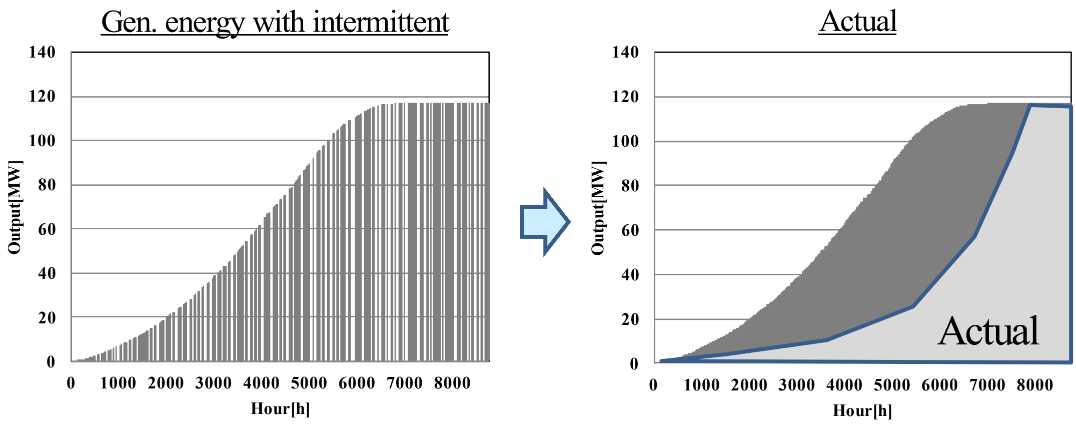
Source: JICA Study Team

Figure 5.6-8　Fuel Price Scenario

5.6.6 Renewable Energy in WASP-IV

It is necessary to describe characteristics of renewable energy precisely in WASP-IV to calculate the least cost for generation development plan. Especially, there are so many advantaged sites in Jordan to operate renewable energy in the point of environment such as wind flow and solar radiation, and NEPCO has a target to introduce totally about 1,700MW of renewable units in the system by 2020.

However, the output from each unit is unstable while operating because the output depends on the condition of such environments (Figure 5.6-9). So it is important to consider the intermittency of its output in simulating renewable energy in WASP.



Source: JICA Study Team

Figure 5.6-9 Image of Intermittency in Renewable Energy

(1) JICA Techniques for simulating in WASP

The Study Team devised three (3) methods to simulate characteristics of renewable unit in WASP-IV as follows;

(i) As thermal unit

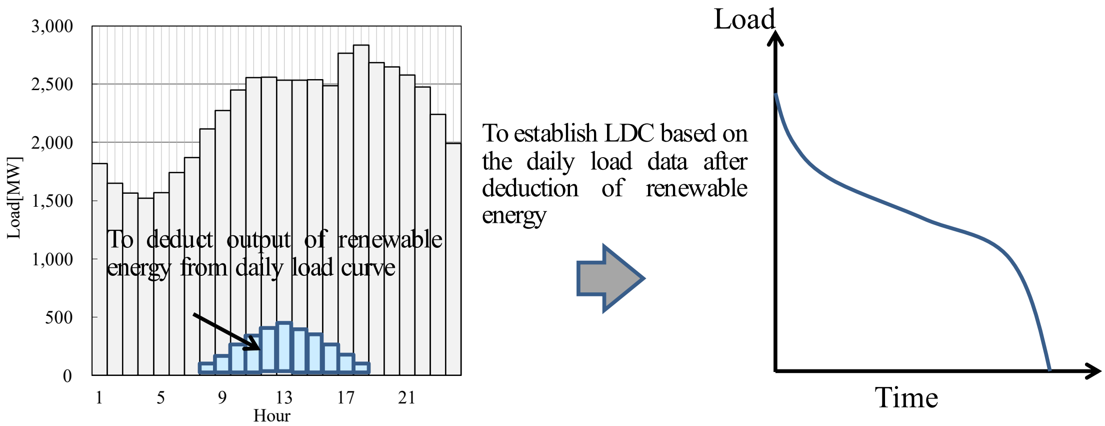
Describe as thermal unit in FIXSYS or VARSYS module of WASP-IV. It can simulate the realistic intermittency of the output by setting the FOR (Forced Outage Rate). On the other hand, it is difficult to simulate the behavior of monthly output of the energy because WASP-IV basically can't set monthly operating capacity.

(ii) As hydro unit

Describe as hydro unit in FIXSYS or VARSYS module of WASP-IV. It can simulate the amount of monthly energy by setting inflow energy and average capacity (in this case, inflow energy can be described as wind flow and solar radiation). However, this method simulates unrealistic situation; all of renewable units will behave as minimum output at the same moment.

(iii) Modification of LDC

This method is to deduct the amount of renewable energy from LDC in advance (Figure 5.6-10). This method is effective in case of simulating the unit which outputs routinely in a day through the period. However, it needs to calculate the daily LDC which is deducted by renewable energy before setting in LOADSY module of WASP-IV.



Source: JICA Study Team

Figure 5.6-10 Image of Modification of LDC

Table 5.6-5 shows the characteristics of each method.

Table 5.6-5 Characteristics of the method for simulating Renewable Energy in WASP-IV

Item	Method (1) "As thermal unit"	Method (2) "As hydro unit"	Method (3) "Modification of LDC"
Capacity factor	Good (can be adjusted)	Good (can be adjusted)	Good (can be adjusted)
Simulation of intermittent	Good	Fair	Poor
LOLP calc.	Good	Poor	Poor
Monthly fluctuation in MW and GWh	Poor	Good	Good
Hour of generation in a day	Poor	Poor	Good
Complexity of calc.	No problem	No problem	More complex

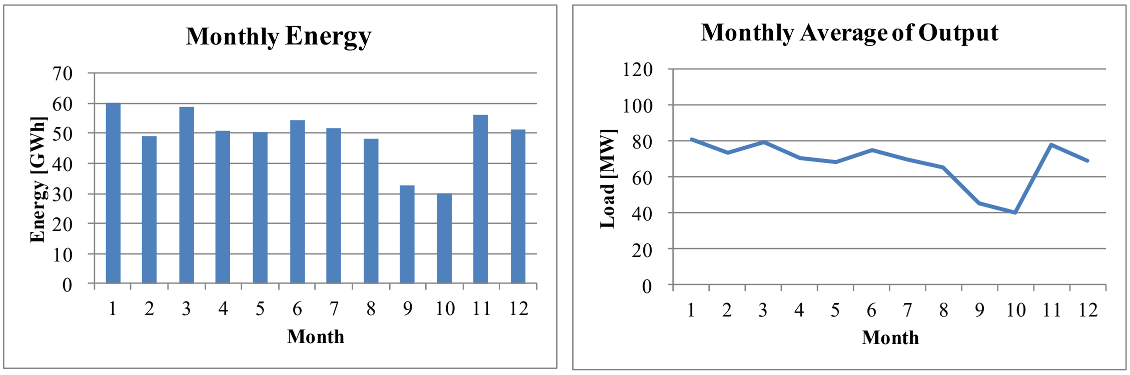
Source: JICA Study Team

(2) Application of the method to the Renewable Energy

This sentence is reported about the application of the methods to simulate the characteristics of renewable unit. To decide the appropriate method for each renewable unit, JICA study team simulated the wind data at Tafila area and solar data at Ma'an area in Jordan.

(i) Wind data

Using the wind data measured in 2002 at Tafila, JICA study team calculated the electric power data as the operating result of wind power units at Tafila (maximum output is set as 117MW). Figure 5.6-11 shows the simulation results of the data. Amount of monthly energy is nearly constant except September and October, and this characteristic is similar to monthly average of output.

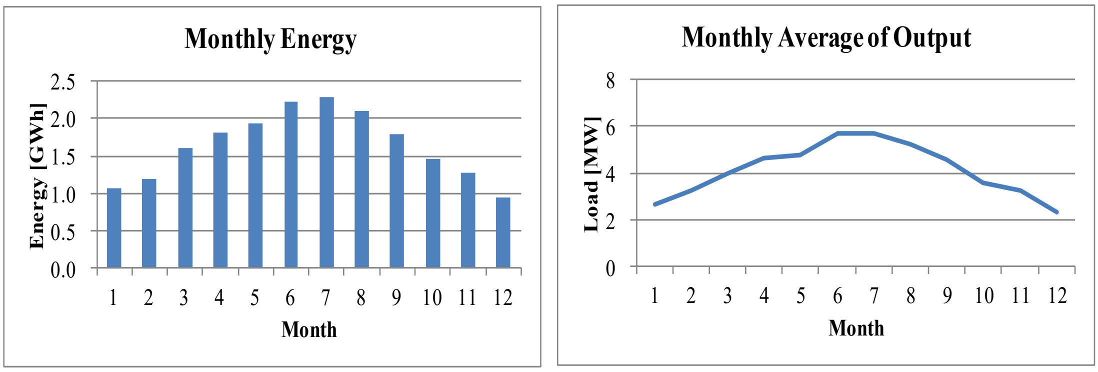


Source: JICA Study Team

Figure 5.6-11 Simulation result of wind data measured in 2002 at Tafila

(ii) Solar data

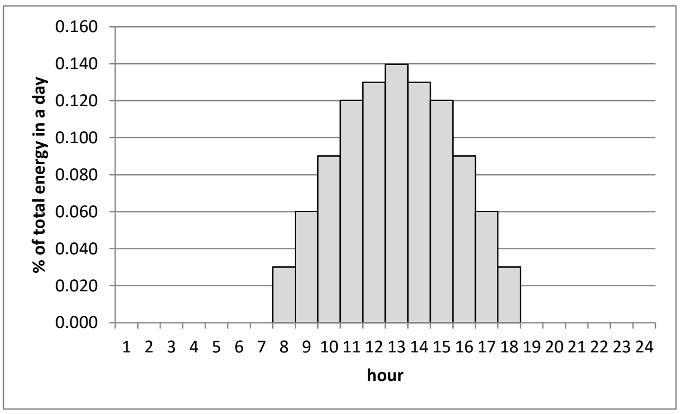
Using the solar data measured from December 2006 to Novenber 2007 at Ma'an, JICA study team also calculated the electric power data as the operating result of solar power units at Ma'an (maximum output is set as 10MW). Figure 5.6-12 shows the simulation results of the data. It is cleared that monthly energy is not flat through the year, but is the highest in summer season.



Source: JICA Study Team

Figure 5.6-12 Simulation result of Solar data measured in 2006 ~ 2007 at Ma'an

It is well known that the output of solar power in chronological order describes typical curve in a day. Figure 5.6-13 shows example of typical output model of solar energy.



Source: JICA Study Team

Figure 5.6-13 Example of typical output model of Solar Energy

Considering above results, JICA study team determined the appropriate method for renewable energy. Method 1 is applied to simulating the wind power unit in the point of the flatness of monthly energy, on the other hand, method 3 is applied to simulating the solar power unit in the point of the routine of daily output. The capacity factors of wind power which will be operated until 2018 are set with each project data, and those of future wind power which will be operated after 2018 are set an average data of committed project which will be operated by 2018. On the other hand, capacity factor of all solar energy are unified as 21%.

Table 5.6-6 Application of the Method to Renewable Energy

Unit	Method	Characteristics
Wind power	1 : As thermal unit	Flatness of monthly energy
Solar Power	3 : Modification of LDC	Routine of daily output

5.6.7 Development Scenario of Generators in Jordan

(i) Development Scenario

For a country which needs to extend large scale of the generation development, it is important to implement the least cost development plan as well as possible.

In this section, six types of the scenario are simulated with WASP-IV, considering the large scale of generation development of oil shale or nuclear power plants, and each of simulation results is evaluated. Table 5.6-7 shows the development scenario of generators in Jordan. In those scenarios, amount of renewable energy is set as 20% of peak demand in each year and the ratio of wind power to solar power is set 1 to 3 as assumption.

Table 5.6-7 Development Scenario of Generators in Jordan

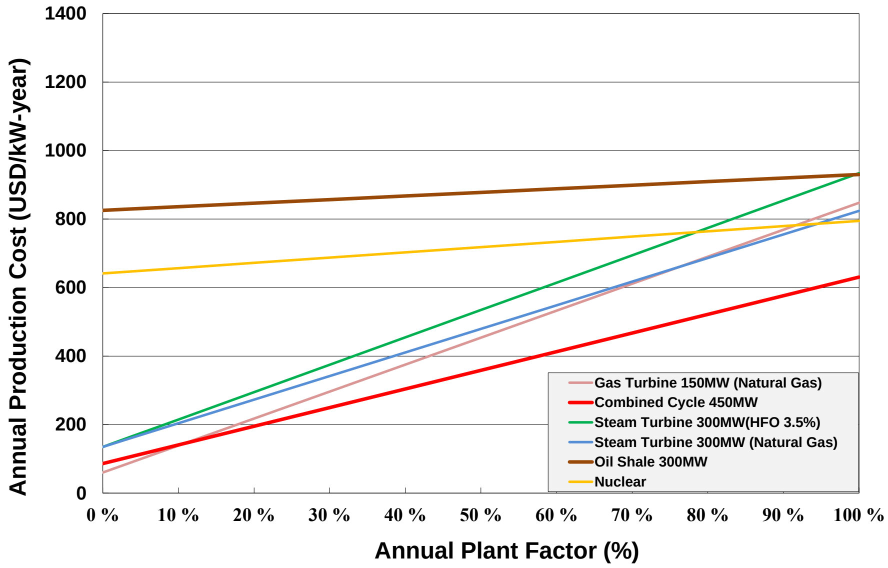
<table>
<tr><th>Scenario</th><th>Nuclear Development</th><th>Oil Shale Development</th><th>Renewable Development</th><th>Natural Gas Supply</th></tr>
<tr><td>Nuclear on schedule 1</td><td rowspan="2">1st Unit: 2023
2nd Unit: 2025</td><td>committed project only</td><td rowspan="6">committed and future project</td><td rowspan="6">Re-gasified gas from LNG at Aqaba

500 MSCFD until 2025
additional after 2025</td></tr>
<tr><td>Nuclear on schedule 2</td><td>unlimited</td></tr>
<tr><td>Nuclear 5years behind schedule 1</td><td rowspan="2">1st Unit: 2028
2nd Unit: 2030</td><td>committed project only</td></tr>
<tr><td>Nuclear 5years behind schedule 2</td><td>unlimited</td></tr>
<tr><td>Nuclear 10years behind schedule 1</td><td rowspan="2">1st Unit: 2033
2nd Unit: 2035</td><td>committed project only</td></tr>
<tr><td>Nuclear 10years behind schedule 2</td><td>unlimited</td></tr>
</table>

(ii) Analysis with Screening Curve

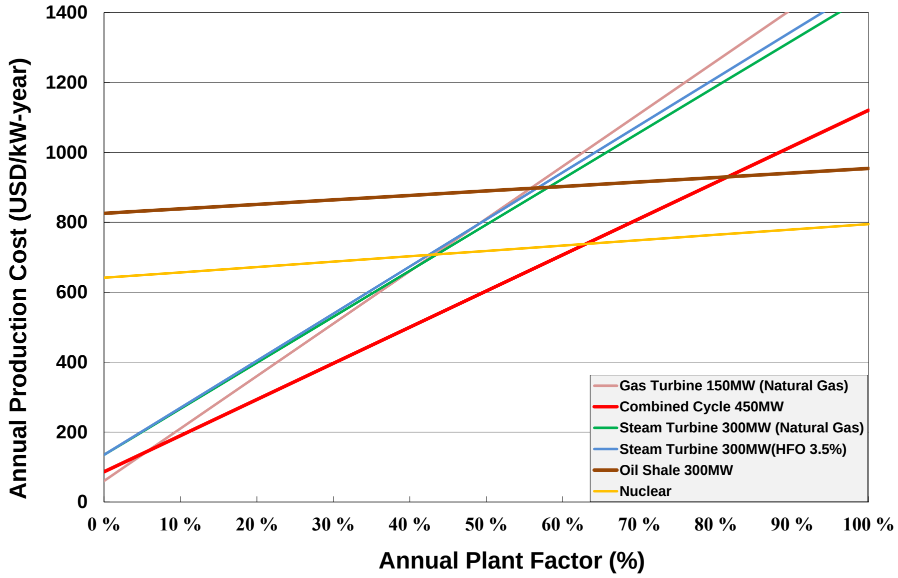
Before formulating the generation development plan using simulation tools, JICA study team conducted a preliminary analysis using the screening curve method. This analysis provides basic information for generation development planning such as the cost of development and operation and the roughly estimated capacity required to develop each candidate unit in the future.

Figure 5.6-14 and Figure 5.6-15 show the result of the screening analysis in each year 2015 and 2034 respectively. As shown in the result, annual production cost of combined cycle will be the lowest in early period of the Study. On the other hand, nuclear power plant will be take the place of combined cycle in high operation in last period of the Study. And it can be seen that the generation cost of oil shale power plant will be lower than that of combined cycle in high operation in 2034.



Source: JICA Study Team

Figure 5.6-14 Results of Screening Analysis (2015)



Source: JICA Study Team

Figure 5.6-15 Results of Screening Analysis (2034)

(iii) Simulation Results

Table 5.6-8 shows the simulation result in case nuclear will be assumed to be developed on schedule. Gray table shows already committed project data, yellow table shows proposely setting data as assumption to be operated, and green table shows the simulation result by WASP calculated in the point of least cost through the study period. It can be seen that only conbined cycle and oil shale are selected as a WASP simulation result and total installed capacity from 2015 is about 8,000MW. Oil shale unit takes the place of combined cycle after 2027, and this results is almost the same as the result of screening analysis. Regarding to renewable energy, ratio of installed capacity of renewable energy to the peak demand in 2019 is about 42%, therefore it is set from 2032 so that the ratio can be lower than 20% of peak demand.

Table 5.6-8 Simulation result of generation development (Nuclear on schedule)

[Unit: MW]

Scenario		Nuclear on schedule 1							Nuclear on schedule 2						
Oil Shale		only committed Project							no limit						
Year	Peak Demand [MW]	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP
2015	3,300					117	0						117	0	
2016	3,493					80	204						80	204	
2017	3,633					0	75						0	75	
2018	3,801			705		172	401				705		172	401	
2019	3,981					245	400						245	400	
2020	4,164			450	470	0	0				450	470	0	0	
2021	4,358			450		0	0				450		0	0	
2022	4,563					0	0						0	0	
2023	4,773					0	0	1,000					0	0	1,000
2024	4,999					0	0						0	0	
2025	5,239					0	0	1,000					0	0	1,000
2026	5,487					0	0						0	0	
2027	5,751					0	0						0	0	
2028	6,030					0	0					300	0	0	
2029	6,323			450		0	0					300	0	0	
2030	6,633					0	0					300	0	0	
2031	6,957			450		0	0					300	0	0	
2032	7,299			450		0	15					300	0	15	
2033	7,654			450		0	53					300	0	53	
2034	8,032			450		0	57					300	0	57	
Developed Capacity(MW)		0	0	3,855	470	614	1,205	2,000	0	0	1,605	2,570	614	1,205	2,000
		8,144							7,994						

Source: JICA Study Team

Table 5.6-9 shows simulation result in case nuclear is developed 5 years behind schedule. Nuclear is installed in 2028 and 2030 which is the year generation cost of oil shale becomes lower than that of combined cycle, therefore oil shale is developed after 2032.

Table 5.6-9 Simulation result of generation development (Nuclear 5years behind schedule)

[Unit: MW]

Scenario		Nuclear 5 years behind schedule 1							Nuclear 5 years behind schedule 2						
Oil Shale		only committed Project							no limit						
Year	Peak Demand [MW]	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP
2015	3,300					117	0						117	0	
2016	3,493					80	204						80	204	
2017	3,633					0	75						0	75	
2018	3,801			705		172	401				705		172	401	
2019	3,981					245	400						245	400	
2020	4,164			450	470	0	0				450	470	0	0	
2021	4,358			450		0	0				450		0	0	
2022	4,563			450		0	0				450		0	0	
2023	4,773			450		0	0				450		0	0	
2024	4,999			450		0	0				450		0	0	
2025	5,239					0	0						0	0	
2026	5,487					0	0						0	0	
2027	5,751					0	0						0	0	
2028	6,030					0	0	1,000					0	0	1,000
2029	6,323					0	0						0	0	
2030	6,633					0	0	1,000					0	0	1,000
2031	6,957					0	0						0	0	
2032	7,299					0	15					300	0	15	
2033	7,654			450		0	53					300	0	53	
2034	8,032			450		0	57					300	0	57	
Developed Capacity(MW)		0	0	3,855	470	614	1,205	2,000	0	0	2,955	1,370	614	1,205	2,000
		8,144							8,144						

Source: JICA Study Team

Table 5.6-10 shows simulation result in case nuclear is developed 10 years behind schedule. By reason of only one unit of nuclear development, more combined cycle or oil shale units are needed. The reason why total developed capacity from 2015 to 2034 in case nuclear 10 years behind schedule 2 is larger than schedule 1 is the simulation result of total generation cost including the penalty charge of energy not served cost is smaller than that of constructing more generation unit.

Table 5.6-10 Simulation result of generation development (Nuclear 10years behind schedule)

[Unit: MW]

Scenario		Nuclear 10 years behind schedule 1							Nuclear 10 years behind schedule 2						
Oil Shale		only committed Project							no limit						
Year	Peak Demand [MW]	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP	GT (Gas)	ST (Gas)	CCGT (Gas)	Oil Shale	Wind	Solar	NPP
2015	3,300					117	0						117	0	
2016	3,493					80	204						80	204	
2017	3,633					0	75						0	75	
2018	3,801			705		172	401				705		172	401	
2019	3,981					245	400						245	400	
2020	4,164			450	470	0	0				450	470	0	0	
2021	4,358			450		0	0				450		0	0	
2022	4,563			450		0	0				450		0	0	
2023	4,773			450		0	0				450		0	0	
2024	4,999			450		0	0				450		0	0	
2025	5,239			450		0	0						0	0	
2026	5,487					0	0					300	0	0	
2027	5,751					0	0					300	0	0	
2028	6,030			450		0	0					300	0	0	
2029	6,323					0	0					300	0	0	
2030	6,633			450		0	0					300	0	0	
2031	6,957					0	0					300	0	0	
2032	7,299			450		0	15					300	0	15	
2033	7,654					0	53	1,000					0	53	1,000
2034	8,032					0	57					300	0	57	
Developed Capacity(MW)		0	0	4,755	470	614	1,205	1,000	0	0	2,955	2,870	614	1,205	1,000
		8,044							8,644						

Source: JICA Study Team

Table 5.6-11 shows total generation cost (object function; 2015 real) of each scenario. Total generation cost is the cost of capital cost, operation and maintenance cost and fuel cost for 20 years between 2015 and 2034. Development of oil shale unit on and after middle stage may contribute the decrease of total generation cost. And the more nuclear development delays, the more total generation cost increases.

Table 5.6-11 Total generation cost of each scenario

Scenario	Nuclear Delay	Oil Shale Development	Total Generation Cost (accumulated)
Nuclear on schedule 1	-	Committed project only	30,785 MUSD
Nuclear on schedule 2	-	Unlimited	30,670 MUSD
Nuclear 5years behind schedule 1	5 years	Committed project only	31,135 MUSD
Nuclear 5years behind schedule 2	5 years	Unlimited	31,077 MUSD
Nuclear 10years behind schedule 1	10 years	Committed project only	31,889 MUSD
Nuclear 10years behind schedule 2	10 years	Unlimited	31,661 MUSD

Source: JICA Study Team

5.7 Optimal generation development plan

Section 5.5-7 reports the result of generation development plan in each scenario only considering the least cost of development plan. However, generation development plan should be optimized taking into consideration not only generation cost but also governmental development policy such as energy mix, energy security, domestic use of energy, environmental aspect, etc.

5.7.1 Characteristics of each power source

It is needed to clarify the characteristic of each power source to consider optimal generation development plan in several aspects. Table 5.7-1 shows the characteristics of each power source in Jordan.

Table 5.7-1 Characteristics of each power source

'Med.'; Medium '-' ; No evaluation

Power Source	Cost			Use of Domestic Energy	Environment	Maturity of Technology	Investment Environment
	Capital	Operation, Maintenance and Fuel	Total				
LNG	Med.	High	Med.	Poor	Good	High	Fair
Oil Shale	High	Low	Med.	Good	Fair	Low	Fair
Renewable Energy (Wind & Solar)	High	Low	High	Good	Good	High	Fair
Nuclear	(High)	(Low)	(Med.)	(Poor)	-	(High)	(Poor)
Coal	High	Low	Low	Poor	Fair	High	Fair

Note; Nuclear is very close to the government development policy. Source: JICA Study Team

(1) LNG

Advantage

-Power generating technology is matured.

-Methodology for environmental evaluation is established.

-Capital cost is lower than that of other power sources.

Disadvantage of weak point

-Unexpected change of gas price which is close relationship with oil price.

-Fuel price is the highest among the power sources.

-Fuel cost occupies a higher position to fuel to the generation cost.

It is difficult to expect future LNG price which will be linked to crude oil price. And development plan mostly depending on combined cycle is not desirable because the generation cost is affected by the unexpected fuel price.

(2) Oil Shale

Advantage

-Oil Shale is a domestic energy.

Disadvantage of weak point

-The number of oil shale project is small, so future development cost is uncertain.

-Carbon intensity is larger than that of combined cycle.

-Water consumption which is necessary for operation is much larger than that of combined cycle.

It is proposed that the 2nd oil shale project should be introduced after evaluating actual performance of Attarat oil shale project (the 1st oil shale project in Jordan).

(3) Renewable Energy

Advantage

-Renewable energy is a domestic energy.

-No fuel cost is necessary.

-Production cost will expected lower in the future (Table 5.3-4).

-Renewable energy is environmentally friendly with less CO_2, NOx and Sox emission.

Disadvantage of weak point

-There is a limit to introducing renewable energy into the power system because its output depends on weather condition.

-Operating reserve by other generator or battery system is necessary to compensate the fluctuation.

(4) Renewable Energy

Advantage

-Power-generating technology is matured.

-Methodology for environmental evaluation is established.

-Fuel price is lower than that of LNG.

Disadvantage of weak point

- Carbon intensity is larger than that of combined cycle.

It is expected to introduce high efficiency coal fired unit in order to save fuel cost and reduce CO_2 emission. And installed capacity will be 600MW at most due to the land availability in Aqaba.

5.7.2 Generation Development Scenario

In light of the characteristics of each power source, some scenarios for power development are formulated as shown in the Table 5.7-2. In all scenarios, generation development plan is simulated with WASP in case nuclear is on schedule and 5 years behind schedule and 10 years behind schedule.

Table 5.7-2 Generation development scenario

Scenario	Characteristic	Generation Development from 2020 to 2034
1. Matured Technology	Only combined cycle units are mainly installed	Combined cycle : depends on the result of WASP simulation Oil shale : Only Attarat Project (470MW) Renewable energy : 20% of system's peak demand Coal : nothing
2. Use of Domestic Fuel	Oil shale unit is more installed than other scenarios because it is a domestic resoure	Combined Cycle : depends on the result of WASP simulation Oil Shale : Attarat Project (470MW) and 300MW x 4 units Second project is assumed to be developed after 2024 to evaluate the performance fo Attarat project Renewable Energy : 20% of system's peak demand Coal : nothing
3. Energy Mix 1	Combined cycle unit and oil shale unit are installed well balanced way	Combined Cycle : depends on the result of WASP simulation Oil Shale : Attarat Project (470MW) and 300MW x 2 units Second project is assumed to be developed after 2024 to evaluate the performance fo Attarat project Renewable Energy : 20% of system's peak demand Coal : nothing
4. Energy Mix 2	Coal fired unit is installed in addition to the Energy Mix 1 scenario	Combined Cycle : depends on the result of WASP simulation Oil Shale : Attarat Project (470MW) and 300MW x 2 units Second project is assumed to be developed after 2024 to evaluate the performance fo Attarat project Renewable Energy : 20% of system's peak demand Coal : 600MW x 1 unit

Source: JICA Study Team

5.7.3 Generation Development Plan in each Scenario

Table 5.7-3 shows generation development plan in scenario 1 (Matured Technoloty). Gray table shows already committed project data, yellow table is proposely setting data as assumption to be operated, green table is the simulation result by WASP calculated in the point of least cost, and orange table is necessary maximum capacity of operating reserve to compensate fluctuation of renewable energy in 10 minutes. Number of developed combined cycle in case nuclear 10 years behind schedule is larger than other cases because of only one development of nuclear unit.

Table 5.7-3 Generation Development Plan in Scenario 1 (Matured Technology)

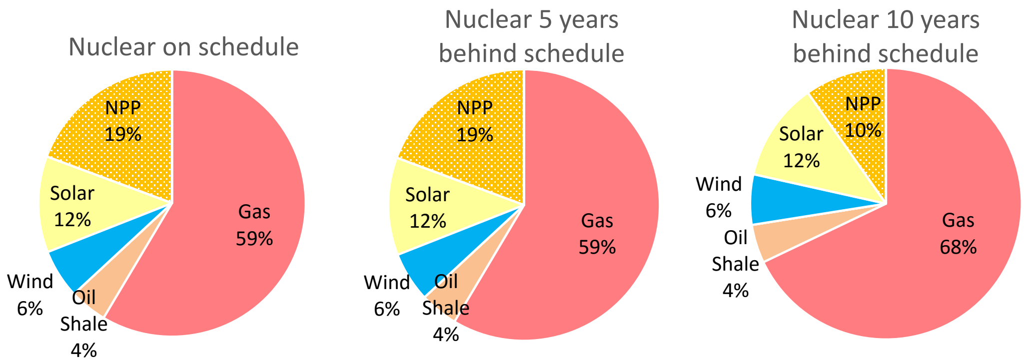
Committed project / Assumed project / WASP proposed project [Unit: MW]

Case			Nuclear on schedule						Nuclear 5years behind schedule						Nuclear 10years behind schedule					
Year	Peak Demand [MW]	Operating Reserve [MW]	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP
2015	3,300	75				117	0					117	0					117	0	
2016	3,493	92				80	204					80	204					80	204	
2017	3,633	100				0	75					0	75					0	75	
2018	3,801	159	705			172	401		705			172	401		705			172	401	
2019	3,981	236				245	400					245	400					245	400	
2020	4,164	237	450	470		0	0		450	470		0	0		450	470		0	0	
2021	4,358	239	450			0	0		450			0	0		450			0	0	
2022	4,563	241				0	0		450			0	0		450			0	0	
2023	4,773	243				0	0	1,000	450			0	0		450			0	0	
2024	4,999	245				0	0		450			0	0		450			0	0	
2025	5,239	247				0	0	1,000				0	0		450			0	0	
2026	5,487	250				0	0					0	0					0	0	
2027	5,751	252				0	0					0	0					0	0	
2028	6,030	255				0	0					0	0	1,000	450			0	0	
2029	6,323	259	450			0	0					0	0					0	0	
2030	6,633	262				0	0					0	0	1,000	450			0	0	
2031	6,957	266	450			0	0					0	0					0	0	
2032	7,299	272	450			0	15					0	15		450			0	15	
2033	7,654	283	450			0	53		450			0	53					0	53	1,000
2034	8,032	294	450			0	57		450			0	57					0	57	
Developed Capacity(MW)			3,855	470	0	614	1,205	2,000	3,855	470	0	614	1,205	2,000	4,755	470	0	614	1,205	1,000
			8,144						8,144						8,044					

Source: JICA Study Team

Figure 5.7-1 shows consumption of installed capacity in 2034 in scenario 1 (Matured Technoloty).

Oil shale accounts for only 4% of total installed capacity in each case, and natural gas accounts for more than 50% of total installed capacity. In this result, these figures include the existing power plants such as SAMRA thermal power units and IPPs which are expected to be still in operation in 2034.



Source: JICA Study Team

Figure 5.7-1 Composition of installed capacity in 2034 in Scenario 1 (Matured Technology)

Table 5.7-4 shows generation development plan in scenario 2 (Use of Domestic Energy). Because of four units of oil shale are developed in addition to Attarat project in 2020, developed number of combined cycle decreases than the result of scenario 1. Development year of oil shale unit in case nuclear is developed schedule is set from 2030 as the result of WASP simulation because of the installation of nuclear unit in 2023 and 2025.

Table 5.7-4 Generation Development Plan in Scenario 2 (Use of Domestic Fuel)

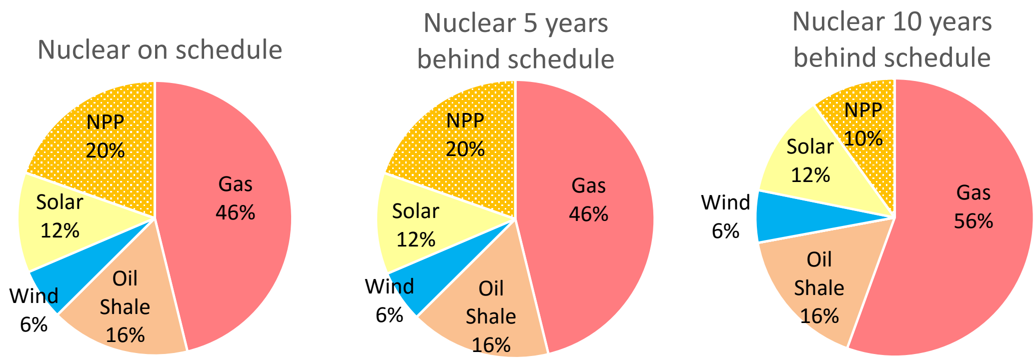
Committed project / Assumed project / WASP proposed project

[Unit: MW]

Case			Nuclear on schedule						Nuclear 5years behind schedule						Nuclear 10years behind schedule					
Year	Peak Demand [MW]	Operating Reserve [MW]	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP
2015	3,300	75				117	0					117	0					117	0	
2016	3,493	92				80	204					80	204					80	204	
2017	3,633	100				0	75					0	75					0	75	
2018	3,801	159	705			172	401		705			172	401		705			172	401	
2019	3,981	236				245	400					245	400					245	400	
2020	4,164	237	450	470		0	0		450	470		0	0		450	470		0	0	
2021	4,358	239	450			0	0		450			0	0		450			0	0	
2022	4,563	241				0	0		450			0	0		450			0	0	
2023	4,773	243				0	0	1,000	450			0	0		450			0	0	
2024	4,999	245				0	0			300		0	0			300		0	0	
2025	5,239	247				0	0	1,000		300		0	0			300		0	0	
2026	5,487	250				0	0			300		0	0			300		0	0	
2027	5,751	252				0	0					0	0			300		0	0	
2028	6,030	255				0	0					0	0	1,000				0	0	
2029	6,323	259	450			0	0					0	0		450			0	0	
2030	6,633	262		300		0	0					0	0	1,000				0	0	
2031	6,957	266		300		0	0					0	0		450			0	0	
2032	7,299	272		300		0	15			300		0	15					0	15	
2033	7,654	283		300		0	53					0	53					0	53	1,000
2034	8,032	294	450			0	57					0	57					0	57	
Developed Capacity(MW)			2,505	1,670	0	614	1,205	2,000	2,505	1,670	0	614	1,205	2,000	3,405	1,670	0	614	1,205	1,000
			7,994						7,994						7,894					

Source: JICA Study Team

Figure 5.7-2 shows consumption of installed capacity in 2034 in scenario 2 (Use of Domestic Fuel). Oil shale accounts for 16% of total installed capacity and takes the place of natural gas.



Source: JICA Study Team

Figure 5.7-2 Composition of installed capacity in 2034 in Scenario 2 (Use of Domestic Fuel)

Table 5.7-5 shows generation development plan in scenario 3 (Energy Mix 1). Number of combined cycle is between the number in scenario1 (Matured Technology) and that in scenario2 (Use of Domestic Fuel).

Table 5.7-5 Generation Development Plan in Scenario 3 (Energy Mix 1)

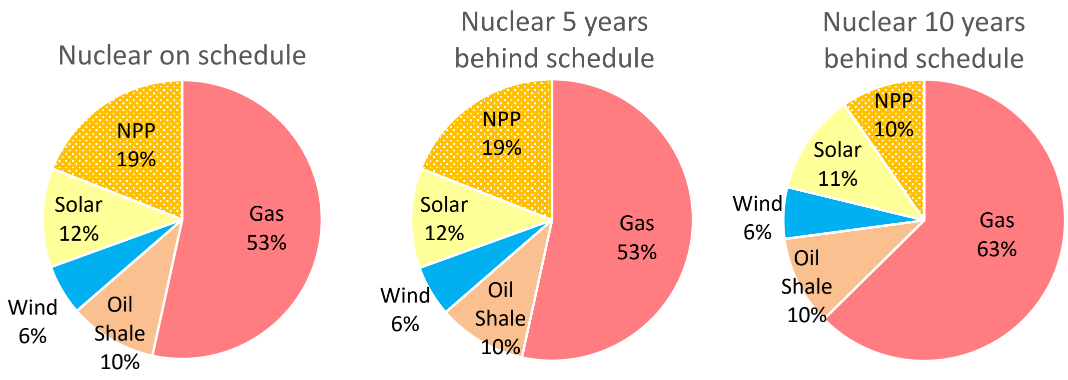
Committed project | Assumed project | WASP proposed project

[Unit: MW]

Case			Nuclear on schedule						Nuclear 5years behind schedule						Nuclear 10years behind schedule					
Year	Peak Demand [MW]	Operating Reserve [MW]	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP
2015	3,300	75				117	0					117	0					117	0	
2016	3,493	92				80	204					80	204					80	204	
2017	3,633	100				0	75					0	75					0	75	
2018	3,801	159	705			172	401		705			172	401		705			172	401	
2019	3,981	236				245	400					245	400					245	400	
2020	4,164	237	450	470		0	0		450	470		0	0		450	470		0	0	
2021	4,358	239	450			0	0		450			0	0		450			0	0	
2022	4,563	241				0	0		450			0	0		450			0	0	
2023	4,773	243				0	0	1,000	450			0	0		450			0	0	
2024	4,999	245				0	0			300		0	0			300		0	0	
2025	5,239	247				0	0	1,000		300		0	0			300		0	0	
2026	5,487	250				0	0					0	0		450			0	0	
2027	5,751	252				0	0					0	0					0	0	
2028	6,030	255				0	0					0	0	1,000				0	0	
2029	6,323	259	450			0	0					0	0		450			0	0	
2030	6,633	262	450			0	0					0	0	1,000				0	0	
2031	6,957	266		300		0	0					0	0		450			0	0	
2032	7,299	272		300		0	15					0	15		450			0	15	
2033	7,654	283	450			0	53		450			0	53					0	53	1,000
2034	8,032	294	450			0	57		450			0	57					0	57	
Developed Capacity(MW)			3,405	1,070	0	614	1,205	2,000	3,405	1,070	0	614	1,205	2,000	4,305	1,070	0	614	1,205	1,000
			8,294						8,294						8,194					

Source: JICA Study Team

Figure 5.7-3 shows consumption of installed capacity in 2034 in scenario 3 (Energy Mix 1). Ratio of oil shale is smaller than scenario 2 (Use of Domestic Fuel), however it accounts for 10% of total installed capacity.



Source: JICA Study Team

Figure 5.7-3 Composition of installed capacity in 2034 in Scenario 3 (Energy Mix 1)

Table 5.7-6 shows generation development plan in scenario 3 (Energy Mix 1). Development year of a coal fired unit is simulated with WASP, and it is cleared that a coal fired unit is installed early time in this study period. The reason is that fuel costs of coal fired and nuclear units are lower than that of combined cycles which will be operated as a base until 2022. And more, daily base load from 2023 is large (mainly over 2,000MW) including holidays.

Installed number of combined cycle decreases compared with the result of scenario3 (Energy Mix 1) because of the installation of a coal fired unit.

Table 5.7-6 Generation Development Plan in Scenario 4 (Energy Mix 2)

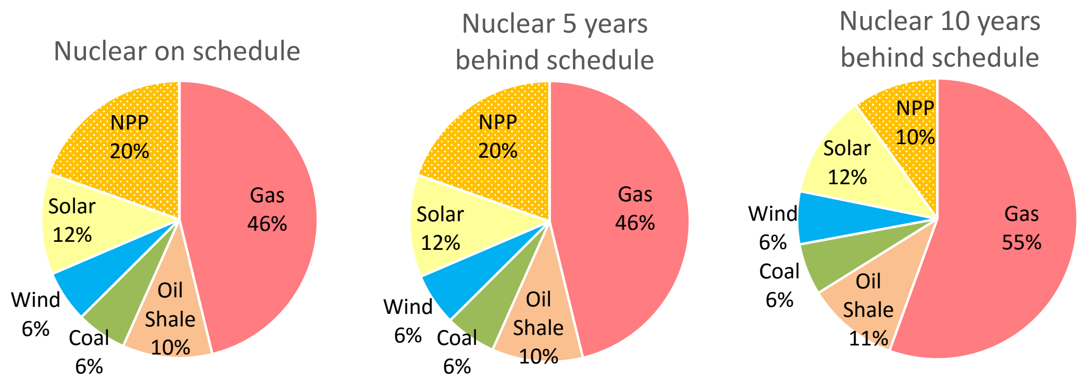
Committed project / Assumed project / WASP proposed project

[Unit: MW]

Case			Nuclear on schedule						Nuclear 5years behind schedule						Nuclear 10years behind schedule					
Year	Peak Demand [MW]	Operating Reserve [MW]	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP
2015	3,300	75				117	0					117	0					117	0	
2016	3,493	92				80	204					80	204					80	204	
2017	3,633	100				0	75					0	75					0	75	
2018	3,801	159	705			172	401		705			172	401		705			172	401	
2019	3,981	236				245	400					245	400					245	400	
2020	4,164	237	450	470		0	0		450	470		0	0		450	470		0	0	
2021	4,358	239	450			0	0		450			0	0		450			0	0	
2022	4,563	241				0	0		450			0	0		450			0	0	
2023	4,773	243				0	0	1,000			600	0	0				600	0	0	
2024	4,999	245			600	0	0			300		0	0			300		0	0	
2025	5,239	247				0	0	1,000		300		0	0			300		0	0	
2026	5,487	250				0	0					0	0					0	0	
2027	5,751	252				0	0					0	0		450			0	0	
2028	6,030	255				0	0					0	0	1,000				0	0	
2029	6,323	259				0	0					0	0					0	0	
2030	6,633	262				0	0					0	0	1,000	450			0	0	
2031	6,957	266		300		0	0					0	0		450			0	0	
2032	7,299	272		300		0	15					0	15					0	15	
2033	7,654	283	450			0	53					0	53					0	53	1,000
2034	8,032	294	450			0	57		450			0	57					0	57	
Developed Capacity(MW)			2,505	1,070	600	614	1,205	2,000	2,505	1,070	600	614	1,205	2,000	3,405	1,070	600	614	1,205	1,000
			7,994						7,994						7,894					

Source: JICA Study Team

Figure 5.7-4 shows consumption of installed capacity in 2034 in scenario 4 (Energy Mix 2). A coal fired unit takes the place of some of natural gas units. Installed capacity of natural gas is reduced by 7~8% from that in scenario3 (Energy Mix 1), to be less than 50% in cases of nuclear on schedule and nuclear 5 years behind schedule.



Source: JICA Study Team

Figure 5.7-4 Composition of installed capacity in 2034 in Scenario 4 (Energy Mix 2)

Table 5.7-7 shows total generation cost (2015 real) except operating reserve cost between 2015 and 2034 in each scenario. Total generation cost is the cost of capital cost, operation and maintenance cost and fuel cost for 20 years between 2015 and 2034. Total generation cost in scenario4 (Energy Mix 2) is the lower among all scenarios. The more nuclear development delays, the more generation cost increases.

Table 5.7-7 Total Generation Cost from 2015 to 2034 (2015 real)

[unit: million USD]

Scenario	Nuclear on schedule	Nuclear 5years behind schedule	Nuclear 10years behind schedule
1. Maturity of Technology	30,785	31,135	31,889
2. Use of Domestic Fuel	30,670	31,202	31,837
3. Energy Mix 1	30,736	31,175	31,908
4. Energy Mix 2	29,330	29,474	30,070

Source: JICA Study Team

Table 5.7-8 shows total pure construction cost (nominal) between 2015 and 2034 in each scenario. Scenario1 (Matured Technology) shows the lowest construction cost and scenario 4 (Energy Mix 2) shows the second lowest construction cost.

Table 5.7-8 Total Pure Construction Cost from 2015 to 2034 (nominal)

[unit: million USD]

Scenario	Nuclear on schedule	Nuclear 5years behind schedule	Nuclear 10years behind schedule
1. Maturity of Technology	15,930	15,930	10,650
2. Use of Domestic Fuel	20,490	20,490	15,210
3. Energy Mix 1	18,390	18,390	13,110
4. Energy Mix 2	17,670	17,670	12,390

Source: JICA Study Team

Taking into consideration above results, scenario 4 (Energy Mix 2) will be the most preferable scenario. Main advantages of introduction of scenario 4 are shown as follows;

- Small impact to the total generation cost in case LNG price hikes up
- Lowest total generation cost compared with other scenarios
- Investment environment is good next to secenario 1 (Matured Technology)

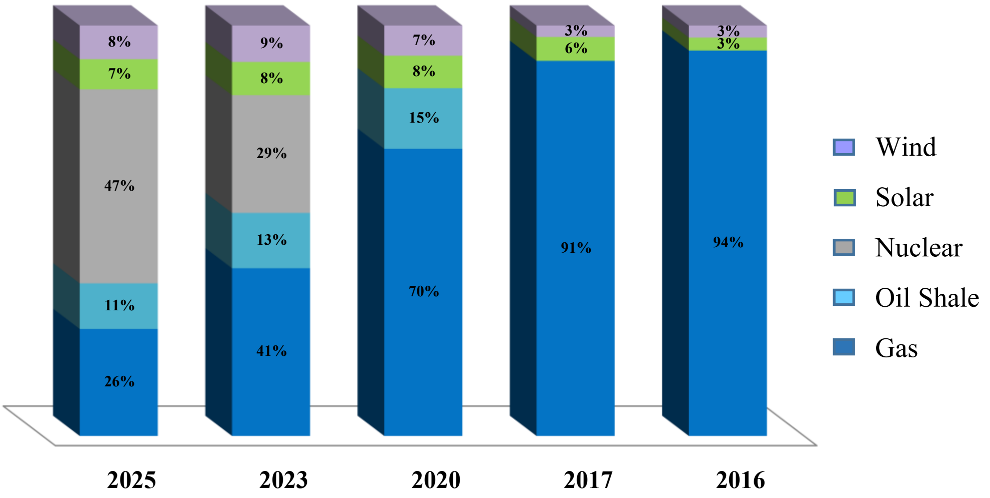
Scenario 2 (Use of Domestic Fuel) would be introduced based on the evaluation of actual performance of Attarat oil shale project.

5.7.4 Installed Capacity of renewable energy in Scenario 4 (Energy Mix)

(1) Generation Development Plan

The Government of Jordan has a target to develop renewable energy as much as 15% of electricity production in a year. Figure 5.7-5 shows composition of energy source from 2016 to 2025 in Energy Sector Strategy in Jordan.

In this section, comparison was made between generation development plan in case renewable energy is developed 20% of peak demand and that in case 15% electricity production based on scenario 4 (Energy Mix 2) which is shown in the Table 5.7-9.



Source: EMRC "Energy Sector Strategy for the period 2015-2025"

Figure 5.7-5 Composition of energy source from 2016 to 2025 in Energy Sector Strategy in Jordan

Table 5.7-9 Energy Mix Scenario

Scenario	Characteristic	Generation Development Plan from 2020 to 2034
4-1. Energy Mix 2-1	Renewable Energy is installed 20% of Peak Demand in addition to the Energy Mix 2 scenario	Combined Cycle : depends on the result of WASP simulation Oil Shale : Attarat Project (470MW) and 300MW x 2 units Second project is assumed to be developed after 2024 to evaluate the performance of Attarat project Renewable Energy : 20% of system's peak demand Coal : 600MW x 1 unit
4-2. Energy Mix 2-2	Renewable Energy is installed 15% of Electricity Production in addition to the Energy Mix 2 scenario	Combined Cycle : depends on the result of WASP simulation Oil Shale : Attarat Project (470MW) and 300MW x 2 units Second project is assumed to be developed after 2024 to evaluate the performance of Attarat project Renewable Energy : 15% of electricity production Coal : 600MW x 1 unit

Source: JICA Study Team

Table 5.7-10 shows generation development plan in scenario 4-2 (Energy Mix 2-2). Total installed capacity of renewable energy is larger than that of scenario 4-1 (Energy Mix 2-1), and it is cleared that installed capacity of renewable energy accounts for 40% of peak demand. The more renewable energy is introducecd, the more operating reserve is increased. The number of combined cycles is the same as in case renewable energy is introduced 20% of peak demand because capacity factor of renewable energy is much lower than that of other thermal unit.

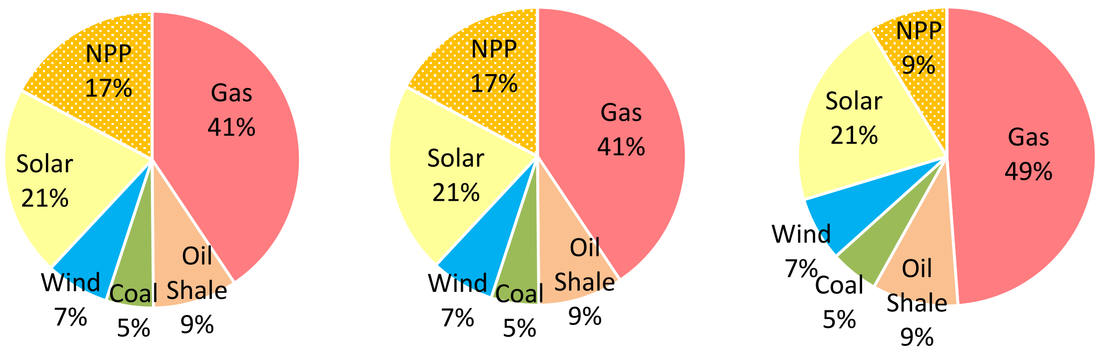
Table 5.7-10 Generation Development Plan in Scenario 4-2 (Energy Mix 2-2)

Committed project / Assumed project / WASP proposed project [Unit: MW]

Case			Nuclear on schedule						Nuclear 5years behind schedule						Nuclear 10years behind schedule					
Year	Peak Demand [MW]	Operating Reserve [MW]	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP	CCGT (Gas)	Oil Shale	Coal	Wind	Solar	NPP
2015	3,300	75				117	0					117	0					117	0	
2016	3,493	92				80	204					80	204					80	204	
2017	3,633	100				0	75					0	75					0	75	
2018	3,801	164	705			172	401		705			172	401		705			172	401	
2019	3,981	236				245	400					245	400					245	400	
2020	4,164	237	450	470		0	0		450	470		0	0		450	470		0	0	
2021	4,358	245	450			0	49		450			0	49		450			0	49	
2022	4,563	258				0	82					0	82		450			0	82	
2023	4,773	270				0	84	1,000			600	0	84				600	0	84	
2024	4,999	284			600	0	90			300		0	90			300		0	90	
2025	5,239	300				0	96	1,000		300		0	96			300		0	96	
2026	5,487	315				0	99					0	99					0	99	
2027	5,751	332				0	106					0	106		450			0	106	
2028	6,030	350				0	111					0	111	1,000				0	111	
2029	6,323	368				18	99					18	99					18	99	
2030	6,633	386				31	93					31	93	1,000	450			31	93	
2031	6,957	405		300		32	97					32	97		450			32	97	
2032	7,299	425		300		34	103					34	103					34	103	
2033	7,654	446	450			35	106		450			35	106					35	106	1,000
2034	8,032	468	450			38	113		450			38	113					38	113	
Developed Capacity(MW)			2,505	1,070	600	803	2,409	2,000	2,505	1,070	600	803	2,409	2,000	3,405	1,070	600	803	2,409	1,000
			9,388						9,388						9,288					

Source: JICA Study Team

Figure 5.7-6 shows consumption of installed capacity in 2034 in scenario 4-2 (Energy Mix 2-2). Renewable energy accounts for 28% of total installed capacity.



Source: JICA Study Team

Figure 5.7-6 Composition of installed capacity in 2034 in Scenario 4-2 (Energy Mix 2-2)

Table 5.7-11 shows total generation cost (2015 real) except operating reserve cost between 2015 and 2034 in each scenario. Total generation cost in scenario 4-2 (Energy Mix 2-2) is smaller than that of scenario 4-1 (Energy Mix 2-1) because of the decrease of operation cost of natural gas unit.

However, result in Table 5.7-11 is not included operating reserve cost such as battery system cost in total generation cost, and it is assumed that total operating reserve cost in scenario 4-2 (Energy Mix 2-2) is higher than that in scenario 4-1 (Energy Mix 2-1).

Table 5.7-11 Total generation cost except operating reserve between 2015 and 2034 (2015 real)

[unit: million USD]

Scenario	Nuclear on schedule	Nuclear 5years behind schedule	Nuclear 10years behind schedule
4-1. Energy Mix 2-1	29,330	29,474	30,070
4-2. Energy Mix 2-2	29,140	29,233	29,792

Source: JICA Study Team

Table 5.7-12 shows total generation cost including operating reserve cost (2015 real) between 2015 and 2034 in each scenario. Total generation cost in scenario 4-2 (Energy Mix 2-2) is larger than that of scenario 4-1 (Energy Mix 2-1). In this calculation, battery is choosed lithium-ion rechargeable battery which is expected to be major battely in future to absorb short span fluctuation of renewable energy output, and estimated as present value of 1,500USD/kW as assumption. However, future cost of battery system is not clear because the development of battery system is not matured. Therefore, battery cost in future is assumed to be the same as present value in this calculation.

Table 5.7-12 Total generation cost including operating reserve by battery between 2015 and 2034 (2015 real)

[unit: million USD]

Scenario	Nuclear on schedule	Nuclear 5years behind schedule	Nuclear 10years behind schedule
4-1. Energy Mix 2-1	29,906	30,050	30,646
4-2. Energy Mix 2-2	30,015	30,108	30,667

Source: JICA Study Team

(2) Characteristics of renewable energy in Jordan system

Table 5.7-13 shows introduction condition of renewable energy in Jordan and in Japan. Capacity factor of renewable energy in Jordan is higher than that in Japan. Geological distribution in Jordan is concentrated such as Ma'an in south area of Jordan, and each generator would operate under the same weather condition. It indicates that each generator fluctuates at the same moment, and could lead to the flucutuation of system frequency. If large capacity of renewable energy is connected into the system near future, it entails risk to cause load shedding due to large scale of system fluctuation.

Stand-by operation of thermal unit is needed to compensate the fluctuation of renewable energy at this moment because there is no plan to introduce battery into the system. However the more introduced renewable energy, the more difficult to compensate the fluctuation by thermal unit timely, because it is next to impossible to predict real-time output of renewable energy with high accuracy.

Table 5.7-13 Introduction condition of renewable energy in Jordan and in Japan

	Jordan	Japan
Annual Capacity Factor	Solar: 21% Wind: over 33%	Solar: 13% Wind: 20%
Geological Distribution	Concentrated	Scattered
Timing of each RE output fluctuation	The same time (to be expected)	Not the same time
System Capacity (2015)	About 3,800 MW (without Egypt)	Over 100,000 MW (60Hz area)
Fluctuation of system frequency by RE output	Large (to be expected)	Small
Existing Generator for Operating Reserve	CCGT	Pumped Storage Hydro Power Conventional Hydro Power

Source: JICA Study Team

(3) Preferable scenario

Taking into consideration above studies, it is preferable to develop in accordance with generation development plan in scenario 4-1 (Energy Mix 2-1) at the moment, and review it after evaluating the performance of renewable energy which will be installed into the system in 2016 and 2017.

Chapter 6 Power System Plan

6.1 Current Situation of Power System in NEPCO

6.1.1 Outline of Power System in NEPCO

The power system is composed of mainly 400kV and 132kV as shown in Figure 6.1-1. The power system is interconnected with that of Syria in the north and Egypt in the south. The voltage of 230kV is partly used in the interconnection line with Syria; however, the interconnection line is separated due to the situations in Syria. The border point between NEPCO and distribution companies is a 132/33kV substation that is called BSP (Bulk Supply Point). The voltage level of the distribution system is 33kV and 11kV.

The power demand is concentrated in Amman, the capital city of Jordan, and located in the north of Jordan. The main power system supplies power from the power generation plants around Amman and that lies in the north and south from Egypt to Amman. Table 6.1-1 and Table 6.1-2 show the transmission line length and substation capacity in NEPCO. The substation total capacity is 11,905MVA. The transmission line lengths of 400kV and 132kV are 924km and 3,579km-circuit respectively.

Table 6.1-3 shows standard conductors of the transmission lines in NEPCO. The line type of ACSR560mm^2 is normally used in 400kV transmission lines and ACSR Zebra in 132kV transmission lines. On the standard scale, double circuits are adopted in the transmission system.

NEPCO is facing serious problems about the increase of the short-circuit capacity of 132kV power system. Therefore, the power system on 132kV is operated in radial system to reduce the short-circuit level.

Table 6.1-1 Transmission line length (km - circuit) (2014)

400kV	230kV	132kV		66kV	Total
		Overhead Line	Underground Cable		
924	17	3,482	97	17	4,537

Source: NEPCO Annual Report (2014)

Table 6.1-2 Main substations installed capacity (MVA) (2014)

400/132/33kV	230/33kV	132/33kV	132/6kV	132/11kV	Total
3,760	100	7,865	155	25	11,905

Source: NEPCO Annual Report (2014)

Table 6.1-3 Standard conductors of transmission line

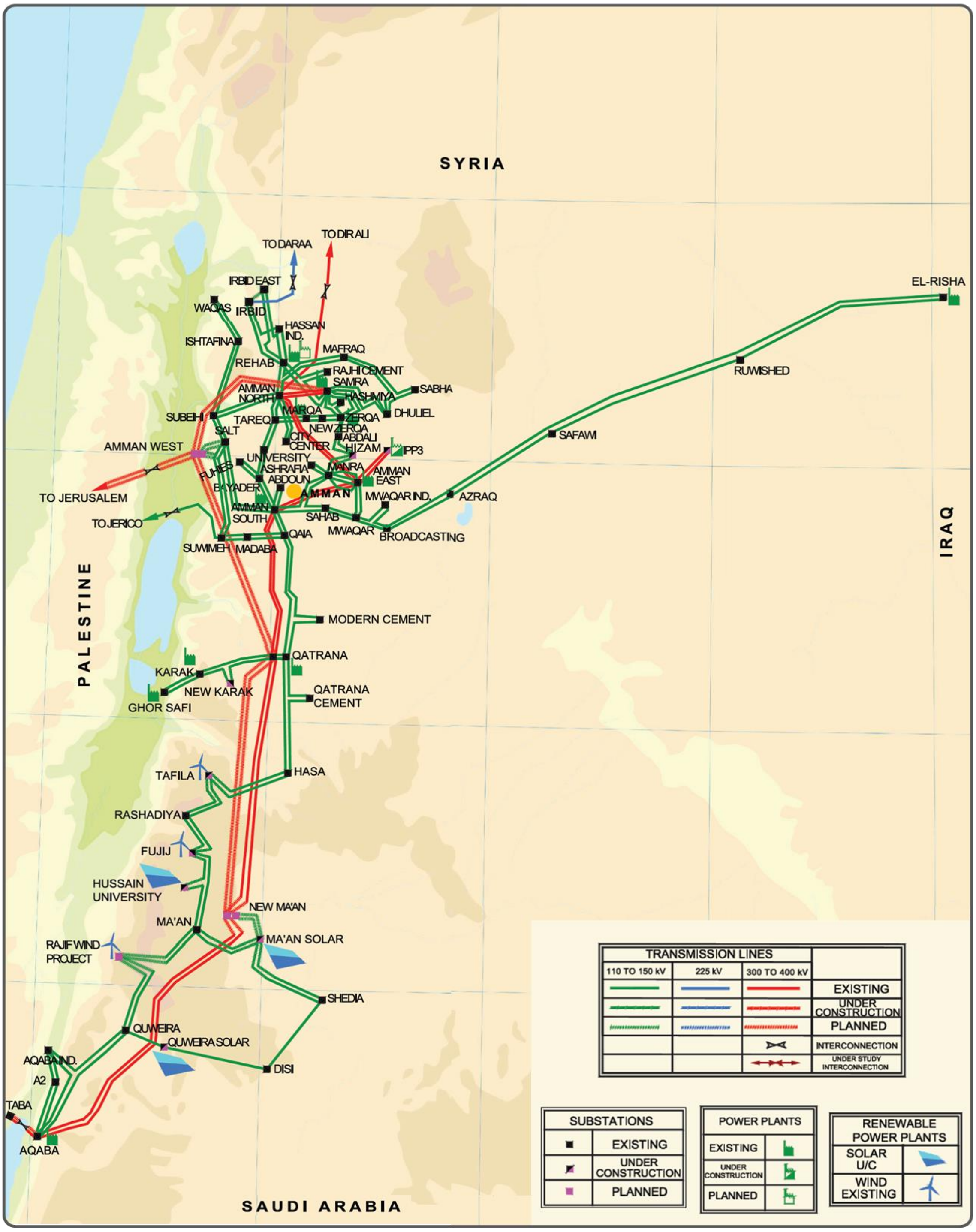
Voltage	Line Type	Size
400kV	ACSR/ACS	560mm^2×3
400kV	ACSR/ACS	560mm^2×2
132kV	ACSR (Zebra)	480mm^2

Source: NEPCO Annual Report (2014)

Table 6.1-4 Standard capacity of transformers（MVA）

Voltage	Capacity (MVA)
400/132kV	400, 240
132/33kV	80, 63, 45, 40, 30

Source: NEPCO Annual Report (2014)



Source: NEPCO Annual Report (2014)

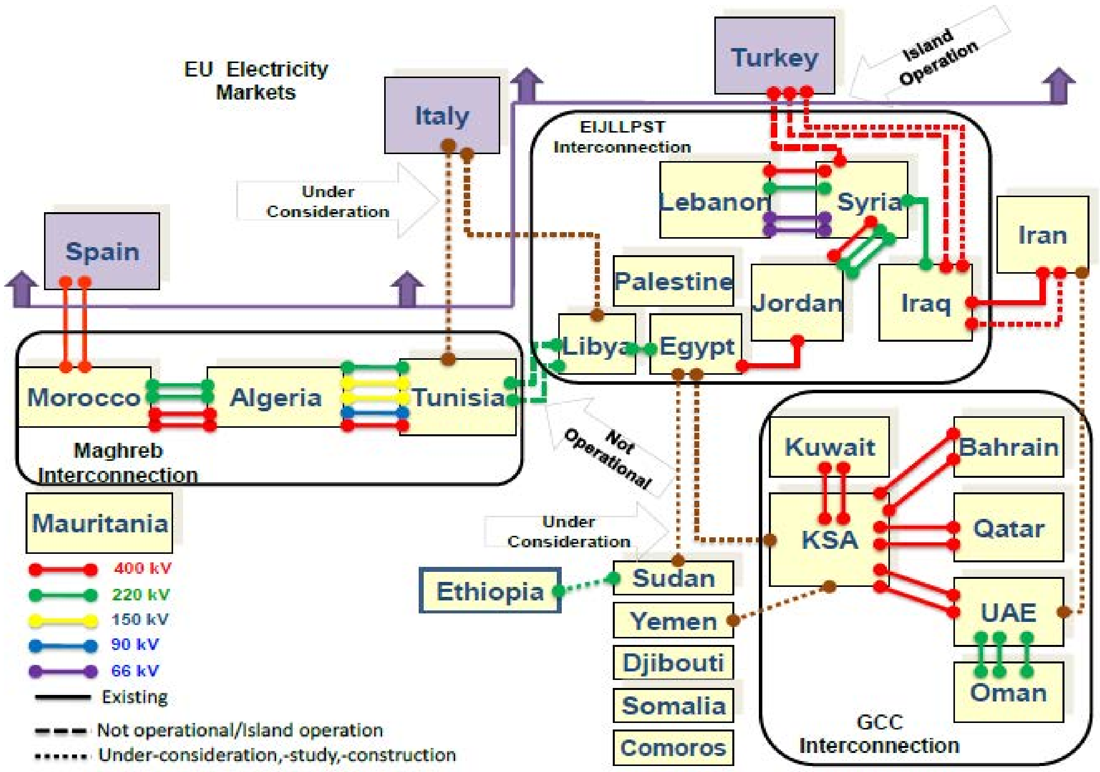
Figure 6.1-1 NEPCO Power System

6.1.2 International Interconnection

The international interconnection with Jordan and surrounding countries is ongoing as the Eight Country Interconnection Project. The eight countries are Egypt, Iraq, Jordan, Libya, Lebanon, Palestine, Syria and Turkey. The electric grids of Libya, Egypt, Jordan and Syria have been interconnected at present.

The transmission line between Jordan and Egypt is interconnected through a 400kV submarine cable at the Gulf of Aqaba and its capacity is 550MW. The Jordan-Syria line is interconnected by 400 kV and 230kV overhead transmissions line and its capacity is 800MW.

There are future plans to interconnect with Saudi Arabia and Palestine in 400kV; however, concrete plan has not been decided yet.



Source: The World Bank, Pan-Arab Interconnection and Development of Arab Power Market

Figure 6.1-2 International interconnection with Syria, Egypt and other countries

6.1.3 Supply Reliability

Table 6.1-5 shows the system average interruption duration (SAIDI) and the system average frequency interruption (SAIFI) per one consumer in 2014.

Table 6.1-5 SAIDI and SAIFI in 2014

System average interruption duration(SAIDI) (minute/year)	System average frequency interruption(SAIFI) (case/year)
27.8	40

Source: NEPCO Annual Report (2014)

6.1.4 Transmission Losses

Table 6.1-6 shows the transmission loss in 2014. The transmission loss is in a low level.

Table 6.1-6 Transmission Loss in 2014

Transmission losses(GWh)	Loss rate (%)
321	1.81

Source: NEPCO Annual Report (2014)

6.1.5 Issues on the Maintenance for Transmission Lines

Table 6.1-7 shows the abnormal example, countermeasures by NEPCO and Japanese approach and technique.

Table 6.1-7 Case examples for abnormarities in the transmission lines and its countermeasures in Japan

Abnormal example	Countermeasures by NEPCO	Japanese approach and technique
Snow damage in Ma'an area (Phase fault for sleet jump or galloping. Conductors breaking, toppling of towers for heavy snow accretion)	➢ Adoption of snow accretionless accessories for conductor - Aluminum snow resistant ring ➢ Tower replacement - Adoption of Short span (400~500m --> 200~300m) - Consideration of snow accretion weight(snow accretion:2 inch)	➢ Reinforcement design for snow accretion ➢ Adoption of snow accretion accessories for conductor - Snow resistant ring, Snow less (SL) cable, Twist prevention damper - Low curie (LC) spiral-rod (Snow melting cable) - High-strength snow resistant tape - Phase spacer
Ground faults due to the dust contamination of insulator	➢ Insulator washing ➢ Insulator change to polymer insulator	➢ Aerodynamic type long rod insulator

6.2 BSP Planning

6.2.1 Current Status and Issues in BSP Planning

(1) BSP Facilities and Operating Rate

BSP is a substation that supplies electricity to distribution companies and large-scaled customers from 132kV power system of NEPCO. Table 6.2-1 shows the outline of BSP facilities. There are 52[1] numbers of BSPs in Jordan at present.

Table 6.2-2 shows the operating rate of BSPs for the maximum peak demand recorded on weekdays in January 2015. And also Figure 6.2-1 shows the distribution chart of BSP operating rate. On the whole, the average operating rate of BSPs is about 41% and this value is in a low level. However the operating rate of some BSPs exceeds 80%, and on the other hand, there are some BSPs whose operating rate is less than 20%. The operating rate of BSPs varies widely. There is a possibility that these BSPs are not allocated optimally.

Table 6.2-1 BSP Facilities in NEPCO

	BSP Name	Capacity of Transformers [MVA]					Installed capacity [MVA]
MIDDLE	ABDALI	40	40				80
	ABDALI NEW	80	80				160
	ABDOON	80	80	80			240
	AMMAN S	45	45	45			135
	AMMAN S NEW	80	80				160
	ASHRFIA	63	63				126
	BAYADER	80	80	80			240
	CITY CENTER	80	80	80			240
	DHULEIL	80	80				160
	FUHEIS	25	25	25			75
	HASHMYA	63	63				126
	MADABA STH	80	80	80			240
	MANARAH	80	80	80			240
	MARQA	45	63	80			188
	MWQAR	80	80				160
	MWQAR IND	80	80				160
	QAIA	45	45				90
	QAIA NEW	80	80				160
	QAIA Manaseer	45					45
	SAHAB	63	63	63			189
	SALT	80	80	80			240
	SUBEIHI	63	63	63			189
	TAREQ	80	80	80			240
	UNIVERSITY	80	80	80			240
	ZERQA	30	30	30	40		130
	ZERQA TR5	63					63
NORTH	HASAN IND	80	80				160
	IRBID	80	60	63			203
	IRBID EAST	80	80				160
	ISHTAFINA	40	45	80			165
	MAFRAQ	80	80	80	80		320
	RAJIHI CEMENT	63	63				126
	REHAB	40	40				80
	SABHA	40	40				80
	WAQAS	63	63				126
EAST & SOUTH	AQ A2	40	40	63	63		206
	AQ IND	80	80				160
	AQTH & NEW	63	63	80	80		286
	AQTH NEW	80	80				160
	AZRAQ	25	25				50
	BROADCAST	40	40				80
	DESI	63	63				126
	EL_HASA	25	25				50
	GHORSAFI	40	40	40	40	40	200
	KARAK	16	16	25			57
	KARAK SOUTH	80	80				160
	MAAN	16	16	16	45	45	138
	MODERN CEMENT	40	40				80
	QATRANA	10	10	16			36
	QATRANA CEMENT	45	45				90
	QUWEIRA	16	45				61
	RASHADIA	16	40	40			96
	RESHA	13	13				25
	RWESHID	10					10
	SAFAWI	10					10
	SHEDIA	40	40				80
	SWEIMEH	80	80	80			240
		Total					8,137

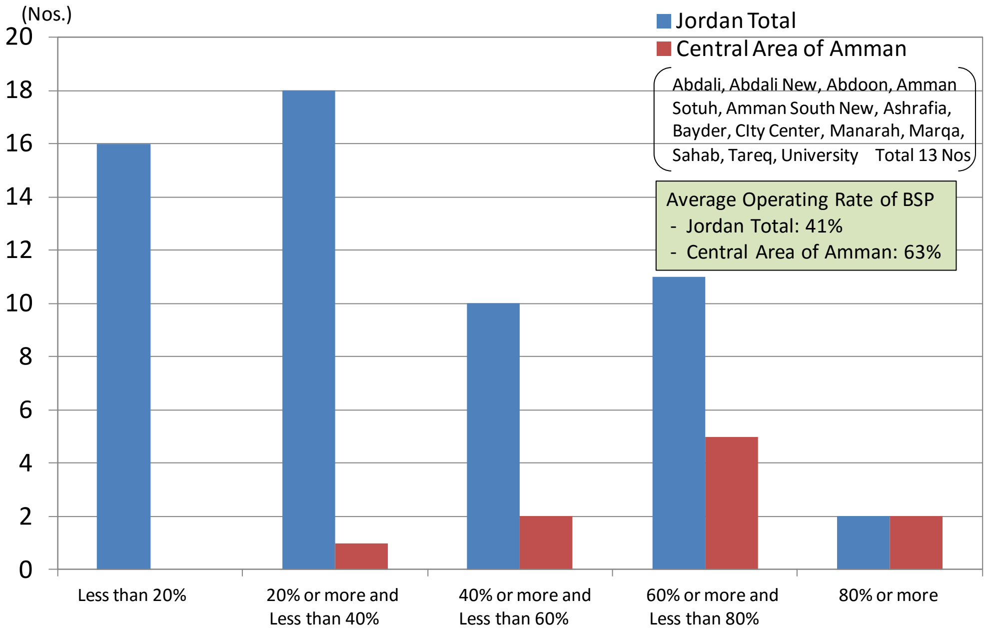
Source: NEPCO

[1] The BSPs of Abdali, Amman South, QAIA, Zerqa and AQTH have new transformers in the same location of the existing BSPs and these BSPs are treated as different BSPs. As for the number of BSPs (52 places), the existing and new BSP are counted one respectively.

Table 6.2-2 Operating Rate of BSP recorded at weekdays in January 2015

	BSP Name	Capacity of Transformers [MVA]					Installed capacity [MVA]	N-1 Capacity [MVA]	Recorded Peak Demand 2015 (Jan.4th) [MVA]	Recorded Peak Demand 2015 (Jan.4th) [%]
MIDDLE	ABDALI	40	40				80	40	53	66%
	ABDALI NEW	80	80				160	80	111	70%
	ABDOON	80	80	80			240	160	109	45%
	AMMAN S	45	45	45			135	90	94	69%
	AMMAN S NEW	80	80				160	80	145	90%
	ASHRFIA	63	63				126	63	98	77%
	BAYADER	80	80	80			240	160	165	69%
	CITY CENTER	80	80	80			240	160	106	44%
	DHULEIL	80	80				160	80	59	37%
	FUHEIS	25	25	25			75	50	0	0%
	HASHMYA	63	63				126	63	28	23%
	MADABA STH	80	80	80			240	160	86	36%
	MANARAH	80	80	80			240	160	51	21%
	MARQA	45	63	80			188	108	172	91%
	MWQAR	80	80				160	80	0	0%
	MWQAR IND	80	80				160	80	44	27%
	QAIA	45	45				90	45	12	13%
	QAIA NEW	80	80				160	80	83	52%
	QAIA Manaseer	45					45	0	0	0%
	SAHAB	63	63	63			189	126	136	72%
	SALT	80	80	80			240	160	131	55%
	SUBEIHI	63	63	63			189	126	103	54%
	TAREQ	80	80	80			240	160	102	42%
	UNIVERSITY	80	80	80			240	160	141	59%
	ZERQA	30	30	30	40		130	90	93	72%
	ZERQA TR5	63					63	0	24	38%
NORTH	HASAN IND	80	80				160	60	51	32%
	IRBID	80	60	63			203	123	133	66%
	IRBID EAST	80	80				160	80	61	38%
	ISHTAFINA	40	45	80			165	85	60	36%
	MAFRAQ	80	80	80	80		320	240	56	17%
	RAJIHI CEMENT	63	63				126	63	13	10%
	REHAB	40	40				80	40	60	75%
	SABHA	40	40				80	40	25	31%
	WAQAS	63	63				126	63	76	60%
EAST & SOUTH	AQ A2	40	40	63	63		206	143	35	17%
	AQ IND	80	80				160	80	20	13%
	AQTH & NEW	63	63	80	80		286	206	26	9%
	AQTH NEW	80	80				160	80	0	0%
	AZRAQ	25	25				50	25	8	17%
	BROADCAST	40	40				80	40	0	0%
	DESI	63	63				126	63	29	23%
	EL_HASA	25	25				50	25	21	42%
	GHORSAFI	40	40	40	40	40	200	160	52	26%
	KARAK	16	16	25			57	32	43	76%
	KARAK SOUTH	80	80				160	80	27	17%
	MAAN	16	16	16	45	45	138	93	62	45%
	MODERN CEMENT	40	40				80	40	27	34%
	QATRANA	10	10	16			36	20	18	50%
	QATRANA CEMENT	45	45				90	45	4	5%
	QUWEIRA	16	45				61	16	15	25%
	RASHADIA	16	40	40			96	56	29	31%
	RESHA	13	13				25	13	0	0%
	RWESHID	10					10	0	4	41%
	SAFAWI	10					10	0	3	32%
	SHEDIA	40	40				80	40	3	4%
	SWEIMEH	80	80	80			240	160	52	22%
									Average	41%

Source: NEPCO



Source: JICA Study Team

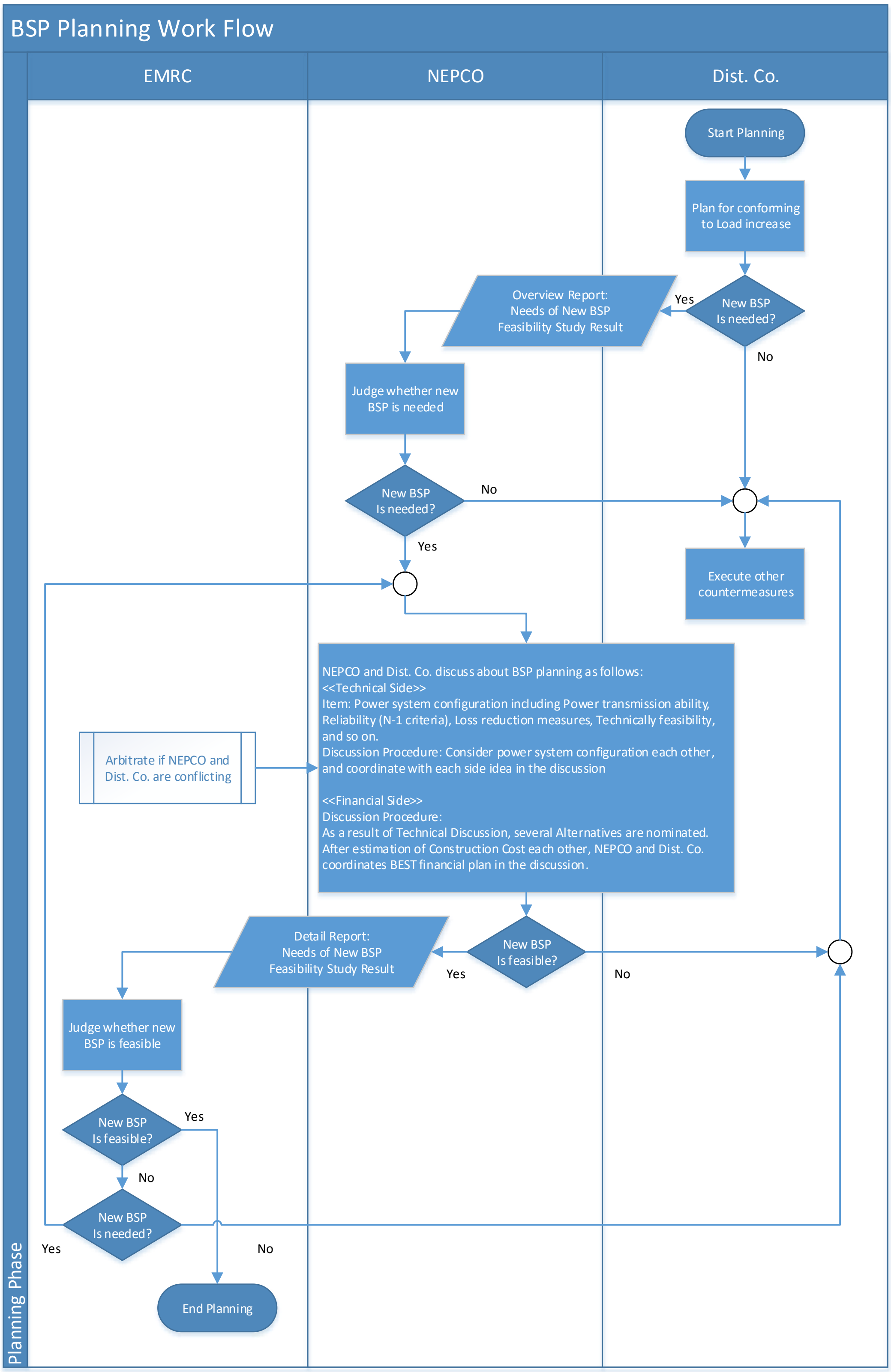
Figure 6.2-1 Distribution Chart of BSPs Operating Rate for the Maximum Peak Demand Recored in January 2015

(2) Current Situations and Issues of BSP Construction Planning

Figure 6.2-2 shows that the work flow diagram for the planning phase of BSP construction. The mainstream of the work flow is as follows.

- Each distribution company collects the load information on each region, and confirms the needs of construction of new BSP and/or distribution network.
- Each distribution company reports the needs of new BSP construction to NEPCO if each distribution company identifies the needs of new BSP construction.
- NEPCO collects the detail information of load situations and required BSP specifications from each distribution company.
- NEPCO review the BSP specifications and related information prepared by each distribution company, and discuss with the Engineers in each distribution company if necessary.
- NEPCO and each distribution company estimates the related construction costs for each candidate site.
- NEPCO and each distribution company select the best BSP allocation from each candidate site by the discussion that includes technical side review and financial side review.
- NEPCO reports the detail BSP construction plan and require the construction of it to EMRC.
- EMRC orders the construction of BSP to NEPCO if EMRC has no objection about the detail BSP construction plan prepared by NEPCO.
- NEPCO and each distribution company construct related facilities of each responsible scope.

Although EMRC has the final decision right of BSP construction plan, but NEPCO has the substantive final decision right for it because EMRC can review only the plans which are arranged by NEPCO finally. Since NEPCO is positioned as the final gate to select the location from some candidate sites.



Source: JICA Study Team

Figure 6.2-2 Work Flow for BSP Construction Planning

Plus, NEPCO should spend all of BSP construction costs except as Distribution Network in the present scheme. From above reasons, NEPCO intends to minimize its outgoing costs within the technical constraints such as power transmission ability. The NEPCO's construction costs include following items.

- Equipment costs for Transmission Line (hereinafter T/L) and BSP
- Personnel costs for construction work of T/L and BSP
- Land acquisition costs of T/L and BSP

The cost items which depend on the BSP location are: T/L construction costs: equipment costs and personnel costs, and land acquisition costs. To minimize the costs of these two items, NEPCO intends to install a BSP near an existing a T/L which is far from demand center and enough short of T/L extension distance.

On the other hand, above situations are not preferable for each distribution company because it makes high distribution line (hereinafter D/L) construction costs and distribution losses due to long D/L length. Recently, the case of Karak South S/S is typical.

In addition, NEPCO is often forced to spend overinvestment of BSP because of real load capacity is much smaller than the load capacity forecasted by each distribution company. The cases of QAIA S/S (Operation Rate = 13[%]) and Manarah S/S (Operation Rate = 21[%]) are the extreme cases.

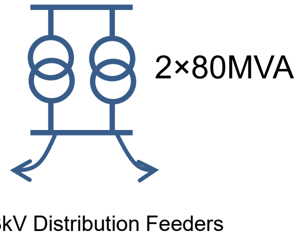
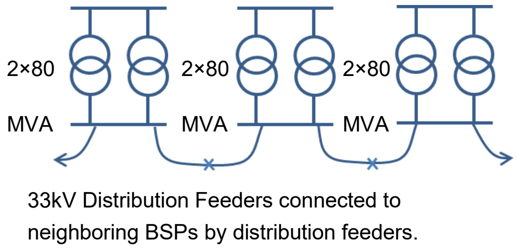
Although the plan of optimized BSP allocation is positioned as one of important issues, but the present scheme won't permit to proceed the optimizing planning.

6.2.2 BSP Planning Methodology

N-1 standard is applied in NEPCO as a BSP planning criteria. In other words, BSP is planned based on the firm capacity of transformers in the state of the loss of one transformer. For example, in the BSP of two numbers of transformers, the firm capacity of BSP is the capacity of one transformer. This means that 50% of BSP transformer capacity is the firm capacity of this BSP.

In this study, BSP grouping methodology that is widely applied in Japanese power companies will be used in the BSP planning. In this BSP planning methodology, several BSPs whose distribution feeders are connected each other are grouped. And it enables an effective utilization of BSP transformers by switching over distribution feeders at the fault of BSP transformers. Table 6.2-3 shows the comparison of BSP planning methodology with the NEPCO practice. The BSP planning steps are as shown in Table 6.2-4.

Table 6.2-3 Comparison of BSP Planning Methdology

Items	NEPCO Practice	BSP Grouping Method
Configuration		
BSP Operating Limit	90%	90% of total operating rate of BSP grouping in principle *1
BSP Capacity in contingency	Capacity at a loss of one transformer In case of two number of transformers: 80MVA	Load transfer level between BSPs is added to the capacity at a loss of one transformer for each BSP For each BSP: 80MVA plus load transfer level

*1 : Operating rate within a BSP group is equalized by switching over 33kV distribution feeders. The number of the switch-over is limited because a switch-over of distribution feeders needs investment.

Table 6.2-4 BSP Planning Steps

Planning Steps	Contents of the Study
Data Collection as a prerequisite for BSP planning	- The data of power demand forecast for each BSP and the load transfer data between BSPs will be collected.
i) BSP Grouping	- Several BSPs will be grouped based on the load transfer level between BSPs and the geographical location of BSPs. - The BSPs where there are no interconnections with the neighboring BSPs by 33kV distribution feeders are not grouped.
ii) Evaluation of BSP operating rate	- In principle, in case that the operating rate of the BSP group exceeds 90%, the countermeasures such as the construction of a new BSP or the reinforcement of existing BSP will be studied. - In case that the operating rate of one of the BSPs in the same BSP group exceeds 90%, the BSP operating rate within a group will be evened by transferring the load to the adjacent BSP. - It should be noted that the upper level of the amount of transferring the load is decided by the present load transfer level; however, the countermeasures such as the construction of a new BSP or the reinforcement of existing BSP will be studied in case of the second time of transferring the load to the adjacent BSPs.
iii) Evaluation of the loss of	- To check the transformer capacity within the firm capacity when

transformer (Fault happens on a transformer)	loss of one transformer by switching over the load to the adjacent BSPs in the short time - In case that the load exceeds the firm capacity of a BSP, some load is switched over the adjacent BSPs in advance to observe the N-1 criteria. - It should be noted that the upper level of the amount of transferring the load is decided by the present load transfer level; however, the countermeasures such as a new BSP or the reinforcement of the BSP will be studied in case of the second time of transferring the load to the adjacent BSPs.
iv) Study on the countermeasures	- In case of the excess of the limitation of BSP operating rate, or the excess of the firm capacity of the BSP, the countermeasures such as a new BSP or the reinforcement of the BSP will be studied - It should be noted that the countermeasures in distribution lines are also to be studied. Cost comparison will be made both transmission side and distribution side. The least cost measures will be selected.

6.2.3 BSP plans

The increase rate of power demand forecast of 5.9% is tentatively applied in the BSP planning because the power demand forecast of each BSP is under ths study by Power Demand Forecast WG at present.

(3) Load transfer level between BSPs and BSP grouping

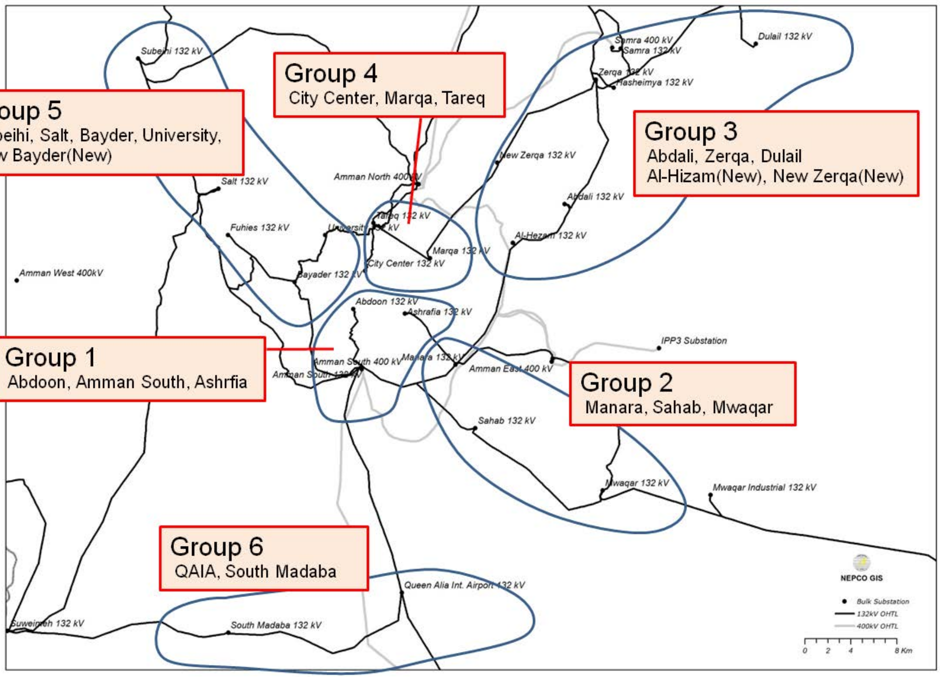
The load transfer level between BSPs has been provided by distribution companies of JEPCO, EDCO and IDECO.Table 6.2-5～ Table 6.2-7 show the load transfer level between BSPs. And also, the BSP groups for each distribution companiesn area decided by the load transfer level are shown in Figure 6.2-3～Figure 6.2-5.

Table 6.2-5 Load Transfer Level between BSPs by JEPCO

No.	Name of BSP	Maximum Demand(MW)	Load Transfer Destination	Transferred Load Percentage
1	Abdali	45	Abdali Ext.	40%
2	Abdoon	160	Bayader	30%
			Tareq	
			City Center	
			Ashrafyeh	
3	Madaba	50	Q.A.Airport	70%
4	Amman South	92.5	Amman South Ext.	45%
			Manara	
			Q.A.Airport	
5	Amman South Ext.	115	Ashrafyeh	55%
			Abdon	

			Manara Amman South	
6	Q.A.Airport	98	Amman South Ext. Madaba	25%
7	Tareq	107	Marka University City Center	75%
8	Alhussain/ Zarqa	94	Abdali Ext. Abdali	20%
9	Alhussain/ Zarqa Ext.	27	Alhussain /Zarqa	100%
10	Abdali Ext.	103	Marka	10%
11	Manara	49	Amman South Abdali Ext. Sahab	100%
12	Mwaqar Industrial	38.5	Sahab	65%
13	Subayhi	8	Salt	65%
14	Dlayl	42	Alhussain Zarqa Ext.	55%
15	Sahab	50	Mwaqar Industrial Q.A.Airport Amman South Ext.	50%
16	City Center	124	Abdon University Ashrafyeh Tareq Marka	90%
17	University	142	Tareq Bayader Salt	60%
18	Marka	150	Abdali Ext. Ashrafyeh City Center	33%
19	Ashrafyeh	95	Manara City Center	54%
20	Bayader	220	University Amman South Ext. Abdon Tareq Salt	36%
21	Salt	118	Subayhi	25%

Source: JEPCO



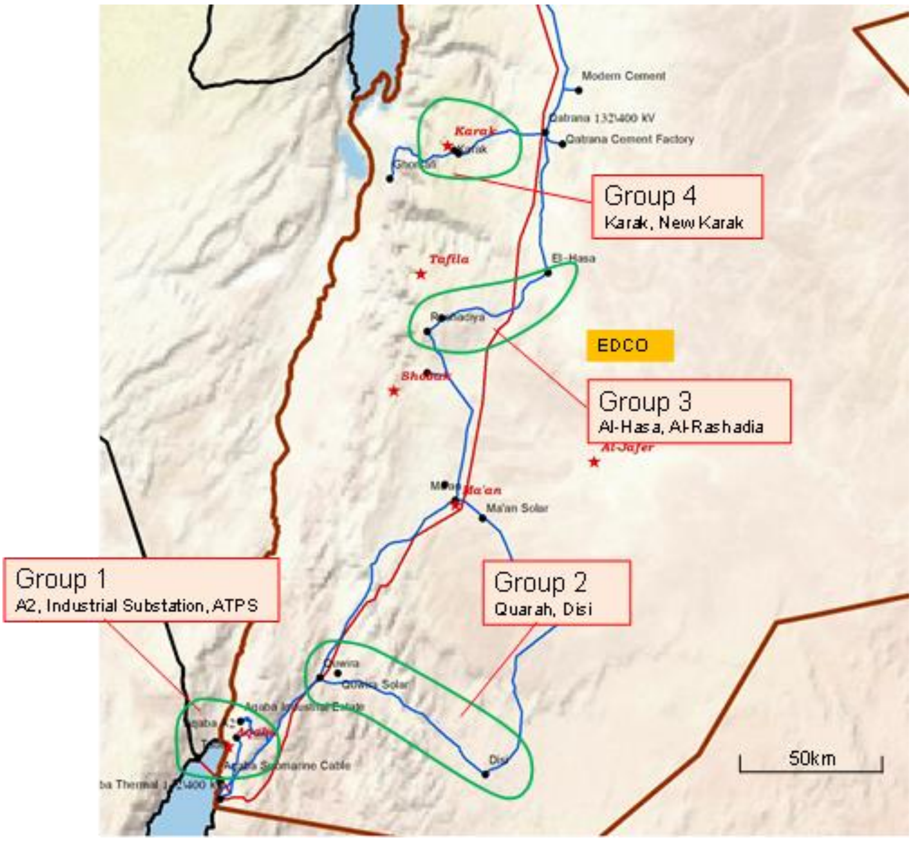
Source: JICA Study Team

Figure 6.2-3 BSP Grouping in Amman Area

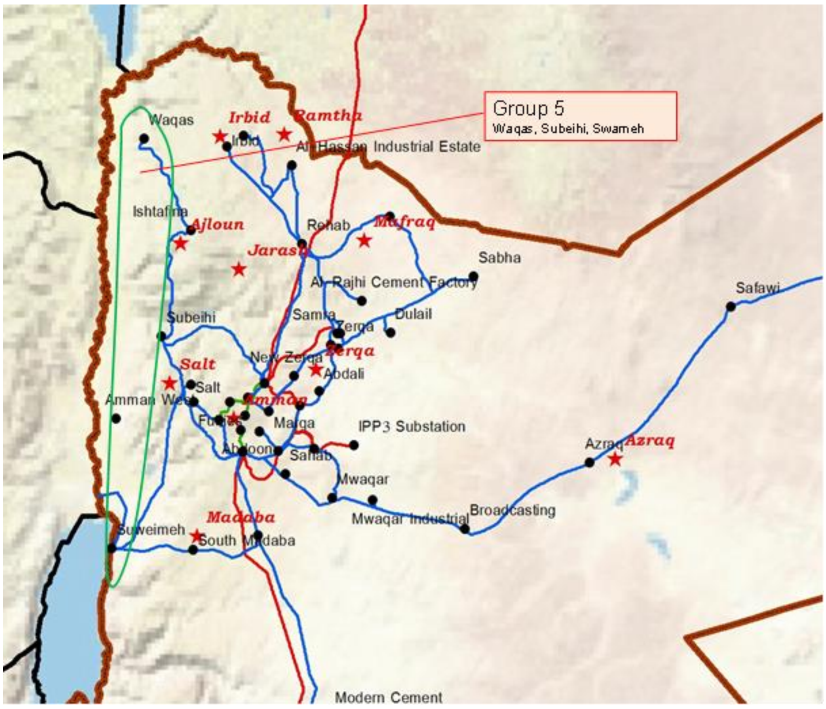
Table 6.2-6 Load Transfer Level between BSPs for EDCO

No.	Name of BSP	Maximum Demand(MW)	Load Transfer Destination	Transferred Load (MW)
1	AQ A2	59.58	AQ IND ATPS	25
2	AQ IND	27.08	AQ A2	15
3	ATPS	27.27	AQ A2	10
4	Quweira	14.55	AQ A2 Desi	6
5	Desi	29.67	Quweira	6
6	El-Hasa	18.87	Al-Rashadia	5
7	Rashadia	24.83	Al-Hasa	5
8	Karak	37.42	Karak South	10
9	Karak South	25.32	Karak	10
10	Subeihi	83.30	Sweimeh Ishtafina	6
11	Sweimeh	67.20	Subeihi	3
12	Ishtafina	60.00	Subeihi Waqas	3
13	Waqas	28.72	Subeihi	3
14	Qatrana	16.12		
15	Ghorsafi	24.58		
16	Ma'an	43.56		
17	Azraq	13.87		
18	Sawafi	0.95		
19	Rweshid	2.87		
20	Resha	3.24		

Source: EDCO



a) South



b) Northwest

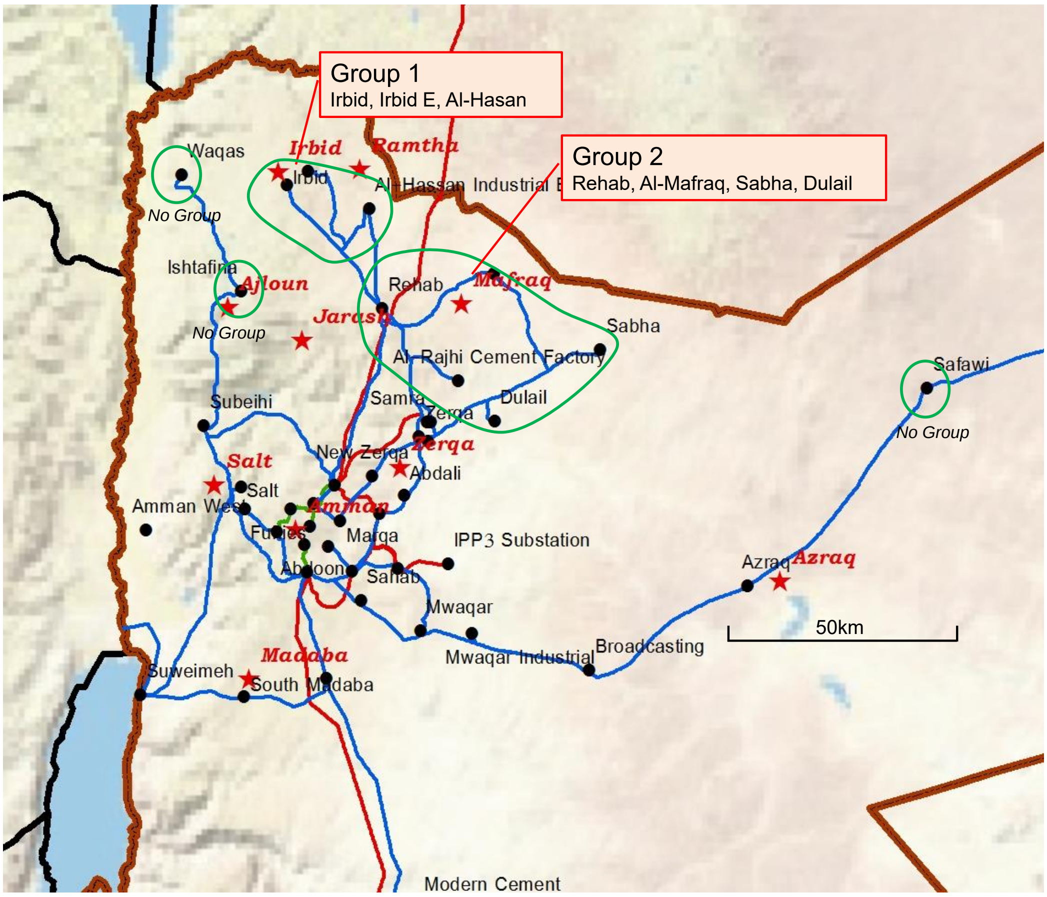
Source: JICA Study Team

Figure 6.2-4 BSP Grouping for EDCO

Table 6.2-7 Load Transfer Level between BSPs for IDECO

No.	Name of BSP	Maximum Demand(MW)	Load Transfer Destination	Transferred Load (kVA)
1	Irbid	117.8	Waqas	57.6
			Irbid East	
			Ishtafina	
			Rehab	
2	Irbid East	81.51	Waqas	22.25
			Irbid	
			Al-Hasan	
3	Al-Hasan	53.56	Irbid East	24.6
			Al-Mafraq	
			Rehab	
4	Waqas	37.72	Ishtafina	25.1
			Irbid	
			Irbid East	
5	Ishtafina	45.15	Rehab	14
			Irbid	
			Waqas	
6	Rehab	45.15	Ishtafina	34.3
			Irbid	
			Al-Hasan	
			Al-Mafraq	
7	Al-Mafraq	56.99	Rehab	48.2
			Al-Hasan	
			Sabha	
			Al-Dhuleil	
8	Sabha	68.42	Al-Dhuleil	25.9
			Al-Mafraq	
			Al-Sawafi	
9	Al-Dhuleil	20.98	Sabha	15.5
			Al-Mafraq	
10	Al-Sawafi	5.72	Sabha	2.6

Source: IDECO



Source: JICA Study Team

Figure 6.2-5 BSP Grouping for IDECO

(4) Construction Unit Cost

Table 6.2-8 shows the constrction unit cost that is used in the BSP cost estimation.

Table 6.2-8 Construction Unit Cost

BSP Unit Cost (Materials and Labor cost)

	Land	Civil	Bays	Transformers	Total (Thousand USD)
New BSP (GIS, Amman) 3-80MVA	6,808	2,458	1,130	1,907	12,303
New BSP (GIS, Amman) 2-80MVA	6,808	2,458	1,130	1,271	11,667
New BSP (AIS)3-80MVA	2723	2,458	328	1,907	7,415
New BSP (AIS)2-80MVA	2723	2,458	328	1,271	6,780
Addition of transformer (Amman)	2723	885	328	636	4,571
Addition of transformer (AIS)	1362	885	328	636	3,210
Addition of transformer (No land cost)	0	443	328	636	1,406

Transmission Line Unit Cost (Materials and Labor cost)

	per km (Tousand USD)
132kV 400mm ACSR Overhead Double Circuit	300
132kV 1000mm Cu XLPE Cable Double	2,000

Distribution Unit Cost (Materials and Labor cost)

	per km (Tousand USD)
33kV 150mm ACSR Overhead	22
33kV 500mm AL XLPE Cable	96

(Source) UPDATE OF THE 2006 GENERATION AND TRANSMISSION EXPANSION MASTERPLAN by ERC(2008) and updated information by NEPCO

(5) Result of the Study

i) BSPs that needs measures

BSP analyses for each distribution company have been conducted. The analysis results are shown in the appendix. Table 6.2-9 shows the BSPs that needs measures from 2016 to 2034. In the BSP analysis up to the year 2019, new BSPs or an additional transformer on BSPs are not needed in consideration of NEPCO ongoing and committed BSP projects.

Table 6.2-9 BSPs that needs measures

Year	JEPCO	EDCO	IDECO
2016～2019	No measures	No measures	No measures
2020	University, Salt, New Bayader, QAIA New	Karak	No measures
2021	No measures	No measures	No measures
2022	Amman South, Abdoon	Ishtafina	Irbid East, Irbid, Hassan Ind.
2023	Muwaqar, City Center, Tareq, Marqa	No measures	No measures
2024	No measures	No measures	Ishtafina

2025	Abdali New, Abdali, Hizam	Azraq	No measures
2026～2034	BSP Group 1-6	BSP Group 5	BSP Group 1, 2

Source: JICA Study Team

ii) Study on the Altanatives for the BSPs that need measures

Cost comparison for the alternatives of new construction, addition of transformer and reinforcements in the distribution lines have been conducted. The results are shown in Table 6.2-10 - Table 6.2-18.

Table 6.2-10 Results of the alternatives for the Group 1 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 1 in JEPCO Supply Area

- Purpose of the study
  Amman South and Abdoon BSP operating rate exceeds 90% in the year of 2022

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2022	New BSP construction (80MVA×3) New Transmission line (5km)	13,803	Reinforcement of Transformers at Amman S BSP (45MVA×3→80MVA×3)	7,415	New distribution lines between Abdoon and Bayader (33kV line 10km, 2cct) Amman S and Manarah (33kV line 10km)	2,880
	New Distribution line (15km)	330	Reinforcement of Transformers at Ashrafia BSP (63MVA×2→80MVA×2)	6,780	Distribution loss	1,301
			New Distribution line (20km)	440		
2023					New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	12,848
2024			Addition of Transformers at Amman S BSP (+80MVA) New Distribution line (10km)	3,960		
2025						
2026						
2027						
2028	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,978	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,978		
2029						
2030						
2031					New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	5,994
Present Value		22,110	－	26,573	－	23,023
Evaluation	○		×		△	

Source: JICA Study Team

Table 6.2-11 Results of the alternatives for the Group 2 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 2 in JEPCO Supply Area

- Purpose of the study
  Muwaqar BSP is not observed N-1 standard in the year of 2023

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2023	New BSP construction (80MVA×2) New Transmission line (5km)	8,280	Addition of Transformers at Mwqar BSP (+80MVA)	4,571	New distribution lines between Sahab and Muwqar (33kV line 20km)	440
	New Distribution line (15km)	330	New Distribution line (10km)	220	Distribution loss	173
2024					Distribution loss	158
2025					New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	7,116
2026						
2027						
2028						
2029						
2030			New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	4,418		
2031						
2032	New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	3,651			New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	3,651
Present Value		12,261	–	9,210	–	11,538
Evaluation	×		○		△	

Source: JICA Study Team

Table 6.2-12 Results of the alternatives for the Group 3 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 3 in JEPCO Supply Area

- Purpose of the study
  Abdali New BSP operating rate exceeds 90% in the year of 2025
  Abdali and Hizam BSP is not observe N-1 criteria in the year of 2025

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2025	New BSP construction (80MVA×2) New Transmission line (5km)	8,280	Addition of Transformers at Abdali New BSP (+80MVA)	4,571	New distribution lines between Hizam,Abdali,Zerqa and New Zerqa (33kV line 40km)	880
	New Distribution line (15km)	330	New Distribution line (10km)	220	Distribution loss	1,386
2026					Distribution loss	1,260
2027					Distribution loss	1,146
2028					Distribution loss	1,042
2029					Distribution loss	947
2030					New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	5,346
2031						
2032			New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	4,418		
2033	New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	4,017				
2034						
	Present Value	12,626	—	9,210	—	12,007
Evaluation	△		○		×	

Source: JICA Study Team

Table 6.2-13　Results of the alternatives for the Group 4 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 4 in JEPCO Supply Area

- Purpose of the study
  City center and Tareq BSP operating rate exceeds 90% in the year of 2023
  Marqa BSP is not observe N-1 in the year of 2023

Discount rate　10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2023	New BSP construction (80MVA×3) New Transmission line (5km)	13,803	Reinforcement of Transformers at Marqa BSP (45→80MVA, 63→80MVA)	11,428	New distribution lines between City Center and Ashrafia (33kV line 10km) Tareq and University (33kV line 10km)	1,920
	New Distribution line (15km)	330	New Distribution line (10km)	220	Distribution loss	195
2024			New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	12,848	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	12,848
2025						
2026						
2027						
2028						
2029	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,978				
2030			New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,252	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,252
2031						
2032						
Present Value		22,110	―	31,748	―	22,215
Evaluation	○		△		△	

Source: JICA Study Team

Table 6.2-14 Results of the alternatives for the Group 5 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 5 in JEPCO Supply Area

- Purpose of the study
  University BSP operating rate exceeds 90% in the year of 2020
  Salt BSP and New Bayder are not observed N-1 standard in the year of 2020

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2020	New BSP construction (80MVA×3) New Transmission line (5km)	13,803	Addition of Transformers at New Bayder BSP (+80MVA)	1,406	New distribution lines between Salt and Subeihi (33kV line 20km) University and Tareq(33kV line 10km)	1,400
	New Distribution line (15km)	330	New Distribution line (10km)	220	Distribution loss	1,497
2021					New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	12,848
2022			New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	11,680		
2023						
2024			Reinforcement of Transformers at Subeihi BSP (63MVA×3→80MVA×3)	3,601		
2025	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	8,775				
2026					New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,978
2027			New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	7,252		
2028						
2029	New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	5,994			New BSP construction (80MVA×3) New Transmission line (5km) New Distribution line (15km)	5,994
Present Value		28,902	–	24,159	–	29,716
Evaluation	△		○		×	

Source: JICA Study Team

Table 6.2-15 Results of the alternatives for the Group 6 in JEPCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 6 in JEPCO Supply Area

- Purpose of the study
  QAIA New BSP is not observe N-1 in the year of 2020

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2020	New BSP construction (80MVA×2) New Transmission line (5km)	8,280	Addition of Transformers at QAIA New BSP (+80MVA)	3,210	New distribution lines between QAIA New and MadabaS (33kV line 20km)	440
	New Distribution line (15km)	330	New Distribution line (10km)	220	Distribution loss	54
2021					Distribution loss	49
2022					Distribution loss	45
2023					New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	6,469
2024						
2025			Addition of Transformers at QAIA BSP (+80MVA) New Distribution line (10km)	1,009		
2026						
2027						
2028						
2029						
	Present Value	8,610	–	4,440	–	7,057
Evaluation	×		○		△	

Source: JICA Study Team

Table 6.2-16 Results of the alternatives for the Group 4 in EDCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 4 in EDCO Supply Area

- Purpose of the study
  Karak BSP do not observe N-1 criteria in the year of 2020

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasure	New BSP		Expansion in the existing BSPs		Reinforcement of distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2020	New BSP construction (63MVA×2) New Transmission line (5km) New Distribution line (15km)	8,280 330	Reinforcement of Transformers at Karak BSP (16MVA×2, 25MVA→63MVA×2, 25MVA×1) New Distribution line (10km)	3,514 220	New distribution lines between Karak and Karak S (33kV line 5km) Distribution loss	110 43
2021					Distribution loss	39
2022					Distribution loss	36
2023					Distribution loss	33
2024					Distribution loss	30
2025					New BSP construction (63MVA×2) New Transmission line (5km) New Distribution line (15km)	5,141 205
2026						
2027						
2028						
2029						
	Present Value	8,610	−	3,734	−	5,637
Evaluation	×		○		△	

Source: JICA Study Team

Table 6.2-17 Results of the alternatives for the Group 5 in EDCO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 5 in EDCO Supply Area

- Purpose of the study
  Ishtafina BSP does not observe N-1 criteria in the year of 2022

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2022	New BSP construction (63MVA×2) New Distribution line (80km)	2,812 1,760	Reinforcement of Transformers at Ishtafina BSP (40,45,63MVA→63MVA×2, 45MVA×1) New Distribution line (30km)	1,757 660	New distribution lines between Ishtafina and Waqas (30km) Distribution loss	660 130
2023					New distribution lines between Subeihi and Ishtafina (30km) Subeihi and Suweimeh (50km) Distribution loss	1,600 197
2024					New BSP construction (63MVA×2) New Distribution line (10km)	2,324 182
2025			Reinforcement of Transformers at Ishitafina BSP (63MVA×2、45MVA×1→63MVA×3) New Distribution line (60km)	1,320 992		
2026						
2027						
2028						
2029						
2030						
2031						
Present Value		4,572	–	4,729	–	5,092
Evaluation	○		△		×	

Source: JICA Study Team

Table 6.2-18 Results of the alternatives for the Group 1 in IDECO

Cost Comparison of BSP Expansion and Distribution reinforcement in Group 1 in IDECO Supply Area

- Purpose of the study
  Irbid BSP operating rate exceeds 90% in the year of 2022
  Irbid East and Hassan Ind. BSP do not observe N-1 criteria in the year of 2022.

Discount rate 10%
Unit: Thousand USD

	Alternative 1		Alternative 2		Alternative 3	
Main Countermeasures	New BSP		Expansion in the existing BSPs		Reinforcement of Distribution lines	
Year	Countermeasures	Cost	Countermeasures	Cost	Countermeasures	Cost
2022	New BSP construction (80MVA×2) New Transmission line (5km) New Distribution line (15km)	8,280 330	Addition of transformer in Irbid East BSP (+80MVA) New Distribution line (10km)	3,210 220	New distribution lines between Irbid E and Al-Hasan (33kV line 20km,2cct) New distribution lines between Irbid E and Irbid (33kV line 10km,2cct) Distribution loss	3,840 440 215
2023					Distribution loss	196
2024					Distribution loss	178
2025			Addition of transformer in Hassan Ind. BSP (+80MVA) New Distribution line (10km)	2,577	Addition of transformer in Irbid East BSP(+80MVA) Addition of transformer in Hassan Ind BSP(+80MVA) Distribution line(20km)	5,154
2026						
2027						
2028						
2029						
2030						
2031	Addtion of 80MVA transformer at New BSP	596	Reinforcement of Transformers at Irbid BSP (80,60,63MVA→80MVA×3) Distribution line(10km)	1,584	Reinforcement of Transformers at Irbid BSP (80,60,63MVA→80MVA×3) Distribution line(10km)	1,584
	Present Value	9,206	–	7,591	–	11,608
Evaluation	△		○		×	

Source: JICA Study Team

Table 6.2-19 shows the summary for the cost comparison.

Table 6.2-19 Summary for the Cost Comparisons

Unit: Thousand USD

Company		JEPCO						EDCO		IDECO
Group		Group1	Group2	Group3	Group4	Group5	Group6	Group4	Group5	Group6
1	New BSP	22,110	12,261	12,626	22,110	28,902	8,610	8,610	4,572	9,026
2	Existing BSP Expansion	26,573	9,210	9,210	31,748	20,558	4,440	3,734	4,729	7,591
3	Distribution lines Reinforce-ment	23,023	11,538	12,007	22,215	29,716	7,057	5,637	5,092	11,608
Selected		1	2	2	1	2	2	2	1	2

Source: JICA Study Team

iii) BSP plans

Table 6.2-20 shows the draft BSP plans up to the year of 2034. The results by the NEPCO practice of the BSP planning are shown in Table 6.2-20. And the processes of the analysis are shown in the appendix (5.3 Draft BSP Plans).

In the BSP analysis up to the year 2019, new BSP or an additional transformer on BSPs are not needed in consideration of NEPCO ongoing and committed BSP projects. On the other hand, 1,043MVA capacity of BSP transformers and 12 numbers of BSPs are needed by the year of 2019.

In the BSP analysis up to the year of 2034, 4,437 MVA capacity of BSP is needed. On the other hand, 6,013 MVA capacity of BSP is needed by the NEPCO practice. 26% reduction of BSP capacity is achived by the BSP grouping methodology compared with the NEPCO practice, which is equivalent to the approximately 30% cost reduction. The detailed results for each distribution company are shown in the appendix. And the power demand forecast necessary for the PSS/E analysis in the Chapter 6.3 is shown in the appendix (5.4 Power Demand Forecast for each BSP).

Table 6.2-20 Draft BSP Plans

Unit: MVA

Year	BSP Grouping Methodology	NEPCO Praticice	NEPCO Committed/Ongoing Projects
2016	-	Amman South New (+80), Karak(+80), Rehab(+80)	Hizam (New), New Bayader (New)
2017	-	QAIA New (+80), Qatrana(+80),	Salt (Add Transformer)
2018	-	Amman South (+105), New Bayader(+80), Subeihi(+80)	New Zerqa (New), Tafila (New)
2019	-	Ashrafia (+80), Muwaqar (+80), JEPCO: New BSP (+240), Irbid (+37)	
2020	New Bayader (+80), QAIA New (+80), Karak (+94)	JEPCO: New BSP (+240), Ashrafia (+34), Subeihi (+17)	
2021	-	-	
2022	JEPCO: New BSP (+480), DECO: New BSP (+240), Irbid East (+80)	EDCO: New BSP (+126). Irbid East (+80)	
2023	JEPCO: New BSP (+240), Muwaqar (+80)	JEPCO: New BSP (+240), Dulail (+80), Quweira(+47)	
2024	Subeihi (+80), Ishtafina (+23)	Abdoon(+80), Zarqa (+100), QAIA (+80), JEPCO: New BSP (+240), Ishtafina (+23)	
2025	Abdali New (+80), QAIA (+80), Azraq (+63), Hassan Ind. (+80)	Azraq (+63), Hassan Ind (+80), Rehab (+40)	
2026	-	+240	
2027	JEPCO G5 (+240)	+80	
2028	JEPCO G1 (+240)	+560	
2029	JEPCO G4 (+240)	+320	
2030	JEPCO G2 (+240) JEPCO G5 (+240)	+480	

2031	JEPCO G6 (+160) IDECO G1 (+160)	+400	
2032	JEPCO G3 (+240)	+160	
2033	JEPCO G1 (+240) JEPCO G5 (+240) IDECO G2 (+160)	+560	
2034	JEPCO G4 (+240) EDCO G5 (+160)	+560	
Total	+4,437	+6,013	

Source: JICA Study Team

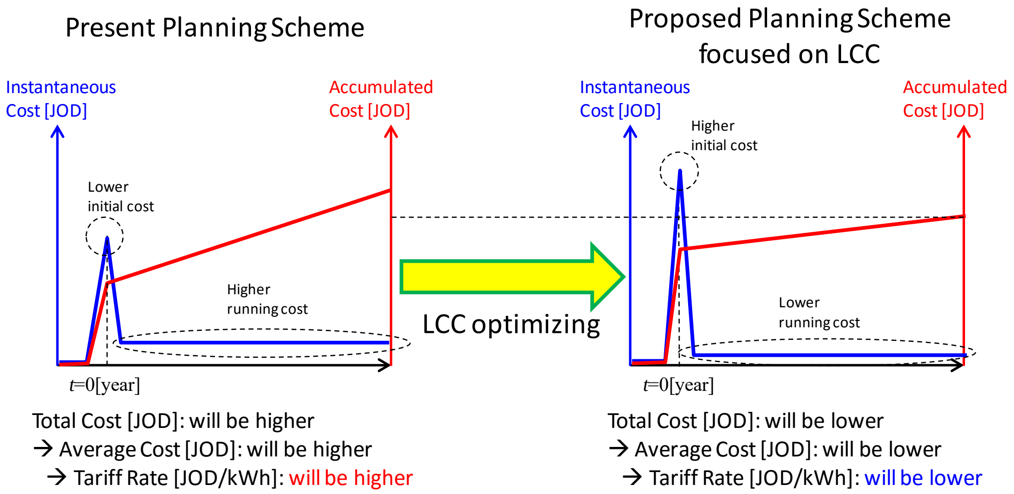
6.2.4 Optimized BSP Allocation Plan

Optimal BSP location planning is difficult in present scheme because of the trade-off relationship of economic damage which depends on the BSP location between NEPCO and distribution companies. Following sections show the solution for it and the results of case study.

(1) Planning Measure for Optimization of BSP Location

(i) Solution, and its Justification

Life Cycle Cost (hereinafter referred to as LCC) is defined as the target indicator of optimization. LCC is defined as the total cost item of the target facility through planning phase, designing, manufacturing, constructing, operation and maintenance, as well as waste or replacement. Therefore, both construction cost focused by NEPCO and operation and maintenance cost focused by distribution companies are handled equally. Also, from long-term viewing, LCC optimization makes reduction of prime cost for electricity power supplying by whole electricity power sector (hereinafter refered to as PCE). As a result, it will make possible to tariff reduction. Figure 6.2-6 shows the overview sketch for LCC optimization.



Source: JICA Study Team

Figure 6.2-6 Overview Sketch of LCC Optimization

To define LCC, following items shall be defined clearly.

- Scope of the system
- Life cycle of the system

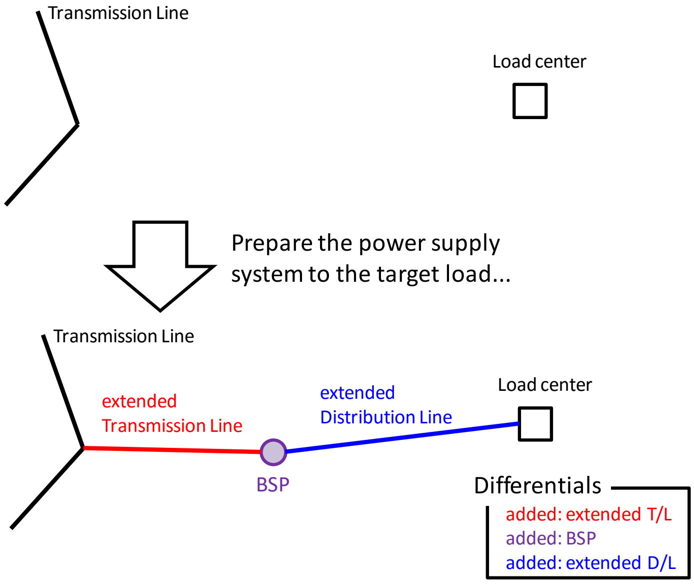
These are defined in following subsections, also LCC for optimization target is defined by them.

(ii) Scope of the System for Optimization of BSP Location

In general, following three investments shown in Figure 6.2-7 are needed to supply electricity power to the constructed new loads.

- Extend transmission line from existing transmission line to new loads, and/or reinforce existing transmission line if necessary.
- Construct BSP at the terminal of transmission line.
- Extend distribution line from BSP to new loads.

Therefore, the scope of the system is consisted by transmission line (extention and/or reinforcement), BSP, and distribution line extention. The distribution network is not included in the scope because this investment is needed in all cases and needs same cost for all cases.



Source: JICA Study Team

Figure 6.2-7 Investments for New Loads

(iii) **System Life Cycle for the Planning of BSP Location Optimization**

Almost system passes through facility planning and designing as starting phase, construction, operation and maintenance up to the life, and waste or replacement as termination phase. BSP also passes through the same life cycle.

The planning measure of BSP location optimization is to select the optimal location from several candidates from the view point of minimizing the LCC. Because the variable elements of LCC depend on only BSP location i.e. length of transmission line, length of distribution line, and BSP construction cost including land acquisition cost, except as given conditions such as specification of existing transmission line (route and voltage) and new load (location and capacity) as well as any other small items.

Table 6.2-21 shows the LCC items for the BSP planning. The items which have dependency of the location and enough large cost are used for the evaluation. The small cost items i.e. planning & designing cost and operation & maintenance cost are omitted.

Table 6.2-21 Life Cycle Items for BSP Location Optimizing Calculation

Phase	Item	Necessity	Descriptions
Planning and Designing	Personnel Cost	No	Enough small
Construction	**BSP Construction Cost**	**Yes**	**Depend on location**
	Extention and/or Reinforcement Cost of Transmission Line	**Yes**	**Depend on location**
	Extention Cost of Distribution Line	**Yes**	**Depend on location**
Operation and Maintenance	**Energy Loss Cost of Transmission Line**	**Yes**	**Depend on location**
	Energy Loss Cost of Distribution Line	**Yes**	**Depend on location**
	Excess Fuel Cost for Generating the Energy Loss of the Power System	**Yes**	**Depend on location**
	BSP Maintenance Cost	No	Enough small
	Transmission Line Maintenance Cost	No	Depend on location but enough small
	Distribution Line Maintenance Cost	No	Depend on location but enough small
Replacement	Replacement Cost of BSP	No	Next life cycle
	Replacement Cost of Transmission Line	No	Next life cycle
	Replacement Cost of Distribution Line	No	Next life cycle

Source: JICA Study Team

(iv) **LCC Definition for Planning of Optimal BSP Location**

LCC is defined as total of the item listed in Table 6.2-21, and this value is positioned as the target for optimization. Therefore, LCC is defined as follows.

$$\mathrm{LCC}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}, \boldsymbol{I}, T, \rho_{\mathrm{E}}\right) = C_{\mathrm{TEx}}\left(L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}\right) + C_{\mathrm{DEx}}\left(L_{\mathrm{D/L}}\right) + C_{\mathrm{D/L}}\left(L_{\mathrm{D/L}}, T, \rho_{\mathrm{E}}\right) + C_{\mathrm{T/L}}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}, \boldsymbol{I}, T, \rho_{\mathrm{E}}\right) + I_{\mathrm{BSP}}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}\right)$$

Formula 6-1

Where

- $\mathrm{LCC}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}, \boldsymbol{I}, T, \rho_{\mathrm{E}}\right)$: Optimization target LCC [JOD]
- $C_{\mathrm{TEx}}\left(L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}\right)$: Cost for extention and/or reinforcement of transmission line [JOD]
- $C_{\mathrm{DEx}}\left(L_{\mathrm{D/L}}\right)$: Cost for extension of distribution line [JOD]
- $C_{\mathrm{D/L}}\left(L_{\mathrm{D/L}}, T, \rho_{\mathrm{E}}\right)$: Economical damage by distribution energy loss [JOD]
- $C_{\mathrm{T/L}}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}, \boldsymbol{L}_{\mathrm{T/L}}, \boldsymbol{I}, T, \rho_{\mathrm{E}}\right)$: Economical damage by transmission energy loss [JOD]
- $I_{\mathrm{BSP}}\left(L_{\mathrm{D/L}}, L_{\mathrm{T/L}}\right)$: BSP construction cost including land acquisition cost [JOD]
- $L_{\mathrm{D/L}}$: Length of extended distribution line [km]

➢ $L_{\mathrm{T/L}}$: Length of extended transmission line [km]

➢ $\boldsymbol{L}_{\mathbf{T/L}} = \left[L^{1}_{\mathrm{T/L}} \quad \cdots \quad L^{M}_{\mathrm{T/L}}\right]^{\mathbf{T}}$: Length vector of reinforced existing transmission line [km]

➢ $\boldsymbol{I} = [I_1 \quad \cdots \quad I_M]^{\mathbf{T}}$: Static current vector of existing transmission line [A]

➢ T: Duration of LCC evaluation [year]

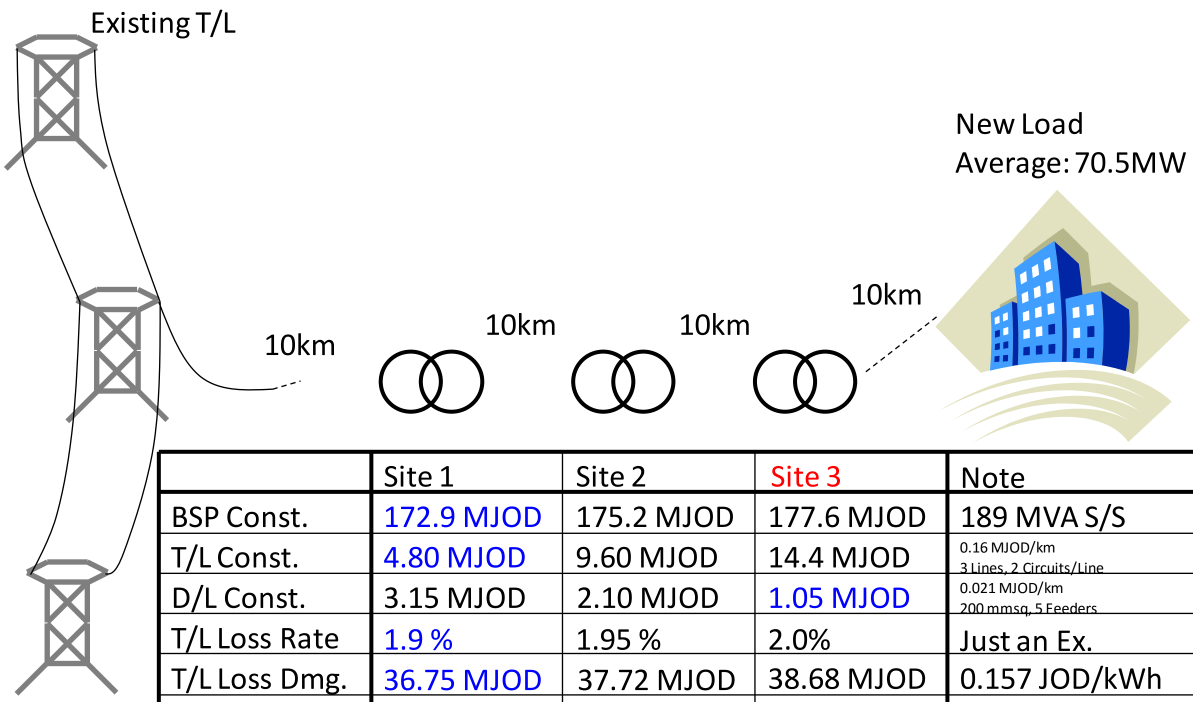
➢ ρ_{E}: PCE [JOD/kWh]

LCC has 6 variables as above, and there are able to be classified by degree of freedom for designing as follows.

➢ Variables directly depend on BSP location: $L_{\mathrm{D/L}}$, $L_{\mathrm{T/L}}$

➢ Decided by only load center location: $\boldsymbol{L}_{\mathbf{T/L}}$

➢ Given conditions: $\boldsymbol{I}, T, \rho_{\mathrm{E}}$



	Site 1	Site 2	Site 3	Note
BSP Const.	172.9 MJOD	175.2 MJOD	177.6 MJOD	189 MVA S/S
T/L Const.	4.80 MJOD	9.60 MJOD	14.4 MJOD	0.16 MJOD/km 3 Lines, 2 Circuits/Line
D/L Const.	3.15 MJOD	2.10 MJOD	1.05 MJOD	0.021 MJOD/km 200 mmsq, 5 Feeders
T/L Loss Rate	1.9 %	1.95 %	2.0%	Just an Ex.
T/L Loss Dmg.	36.75 MJOD	37.72 MJOD	38.68 MJOD	0.157 JOD/kWh
D/L Loss Rate	12.3 %	11.8 %	11.3 %	Just an Ex.
D/L Loss Dmg.	237.9 MJOD	228.2 MJOD	218.6 MJOD	0.157 JOD/kWh
Total LCC	455.5 MJOD	452.9 MJOD	450.3 MJOD	T=20[years]

Refer to NEPCO Annual Report 2014

Source: NEPCO

Figure 6.2-8 Overview Sketch of BSP Construction Site Selection by using LCC

Therefore, BSP location is positioned as a unique variable for LCC variation. In general, the candidate site of BSP construction is selected to few locations by some constraints. This planning measure selects the minimum LCC location from the nominated sites such as Figure 6.2-8. If the candidate site can be selected freely from wide area e.g. along the road without any obstacles for enough long length, the site can be identified by the optimal calculation which uses LCC as evaluation function.

(2) **Case Study of Subeihi S/S**

To confirm the effectiveness of optimization measure for BSP construction location defined in (1), JICA study team calculate transmission / distribution energy losses and LCC for nominated 5 sites at the case of Subeihi S/S managed by EDCO[2].

Table 6.2-22 shows the fundamental information of Subeihi S/S. Also, Figure 6.2-9 and Table 6.2-23 show the details of 5 nominated candidate sites. The 5 candidate sites are selected by the conditions which require flat land without any obstacles. Also, the model for this case study is simplized to concentrated load model like as Figure 6.2-10.

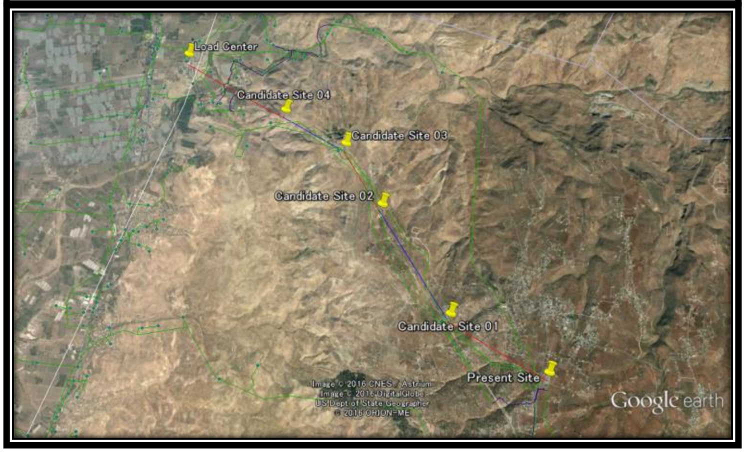
Table 6.2-22 Fundamental Information of Subeihi S/S

Item	Value [Unit]
Location	32°8'9.83"N 35°42'10.61"E
Capacity	189[MVA] (63[MVA]×3[units])
Rated Voltage	Primary; 132[kV] Secondary.: 33[kV]
Peak Demand (FY2013)	81.0[MW] (S/S outlet)
S/S connected by 132 kV system	Ishtahina S/S Amman North S/S Salt S/S
Main Feeders	For water sector: 4 feeders General use for JEPCO: 3 feeders General use for EDCO: 2 feeders Accelerator: 1 feeder KARAMA dum: 1 feeder

Source: NEPCO, EDCO

2 Refer to 7.1.4

Bird's Eye Viewing of Subeihi S/S Candidates



Enlarged Viewing of Subeihi S/S Candidates

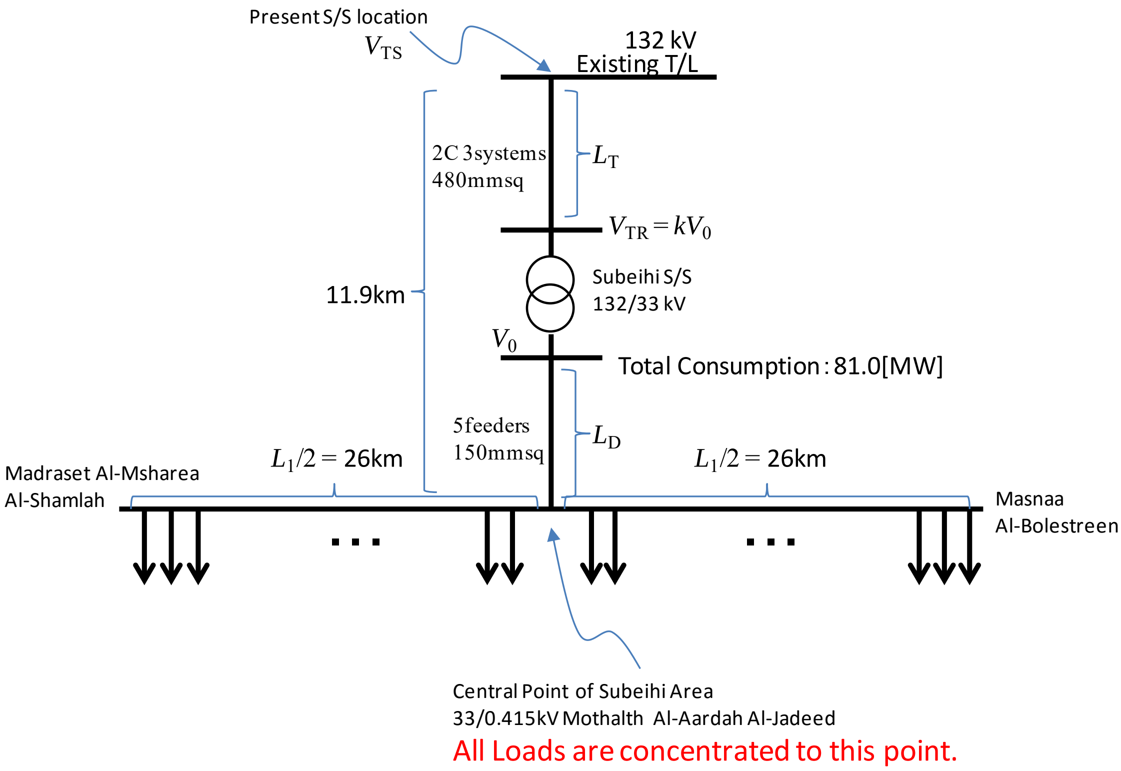
Source: JICA Study Team

Figure 6.2-9　5 Candidate Sites of Subeihi S/S for calculation

Table 6.2-23　Detail Information for 5 Candidate Sites of Subeihi S/S

Name	Details
Site 0 (Present Site)	32°8'9.83"N, 35°42'10.61"E Distance for the load center: 11.9[km]
Site 1	32°8'43.73"N, 35°41'2.54"E Distance for the load center: 9.28[km]
Site 2	32°9'48.62"N, 35°40'15.15"E Distance for the load center: 6.35[km]
Site 3	32°10'27.11"N, 35°39'48.59"E Distance for the load center: 4.64[km]
Site 4	32°10'50.82"N, 35°39'2.33"E Distance for the load center: 2.87[km]
[Reference] Load Center	32°11'30.03"N, 35°37'45.35"E

Source: JICA Study Team



Source: JICA Study Team

Figure 6.2-10 Calculation Model for LCC of Subeihi S/S

Transmission / Distribution energy losses are calculated using the model defined in Figure 6.2-10 and following conditions.

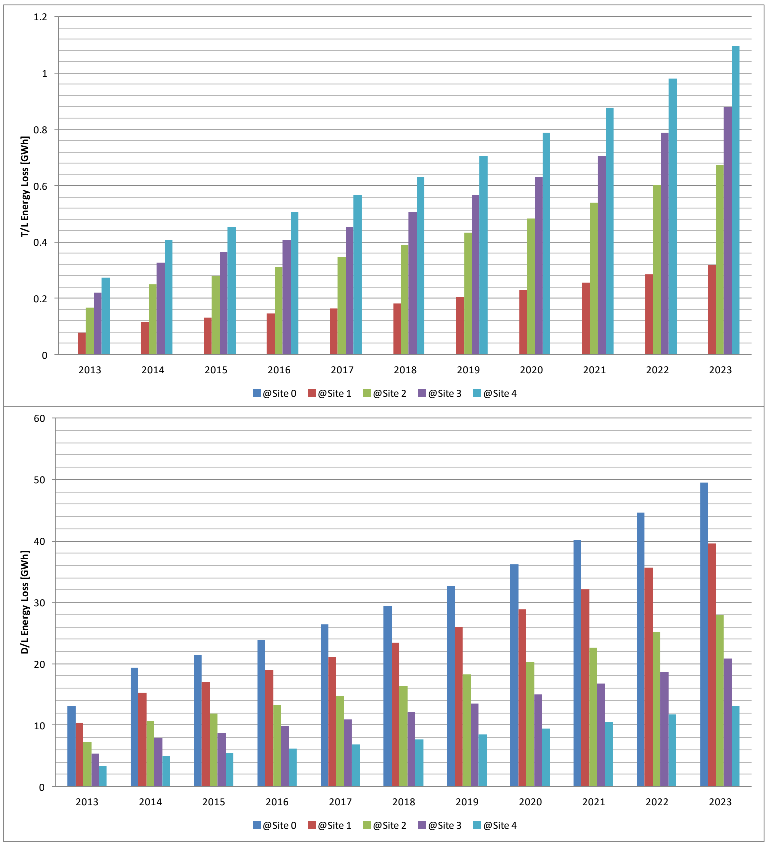
Table 6.2-24 Calculation Conditions for Transmission / Distrubution Energy Losses and LCC

Item	Value	Unit	Source / Descriptions
Peak demand	81.0	MW	Chapter 4 Outlet of S/S sec. side
Demand growth rate	5.65	%	Rough Calculate using Chapter 4
Load factor	0.70	-	Chapter 4
Loss factor	0.553	-	Calculate using following data ・Load factor ・α=0.3
Hours per year	8,766	h/year	365.25 [days/year]
Power factor	0.88	-	EMRC At least over 0.88 because the user who uses power under PF 0.88 shall pay penalty tariff.

Item	Value	Unit	Source / Descriptions
Evaluation term	2023	FY	At FY2024 the capacity of S/S will be short, so the limit of evaluation shall be up to FY2023
PCE (FY2013)	0.1453	JOD/kWh	NEPCO Annual Report
PCE (FY2014)	0.1566	JOD/kWh	NEPCO Annual Report
PCE (after FY2015)	0.1444	JOD/kWh	NEPCO Annual Report Average between FY2011 to FY2014
BSP material cost	16.1	kJOD/MVA	NEPCO Master Plan
Minimum land acquisition cost	2.72	MJOD	NEPCO Master Plan For Site 0
Maximum land acquisition cost	6.81	MJOD	NEPCO Master Plan For Site 4 Land acquisition cost for each site is calculated using linear interpolation, minimum and maximum cost.

Source: JICA Study Team

Figure 6.2-11 shows the calculation results of transmission / distribution losses, and Figure 6.2-12 shows the total of them. This figure clearly shows extention of transmission line to load center as near as possible is effective from the view point of transmission / distribution losses. At 10 years later, power demand will grow to twice by now, as well as transmission / distribution losses will grow quadruple from now. From the present Jordanian situation of rapidly power demand growth, the optimal BSP planning is important.

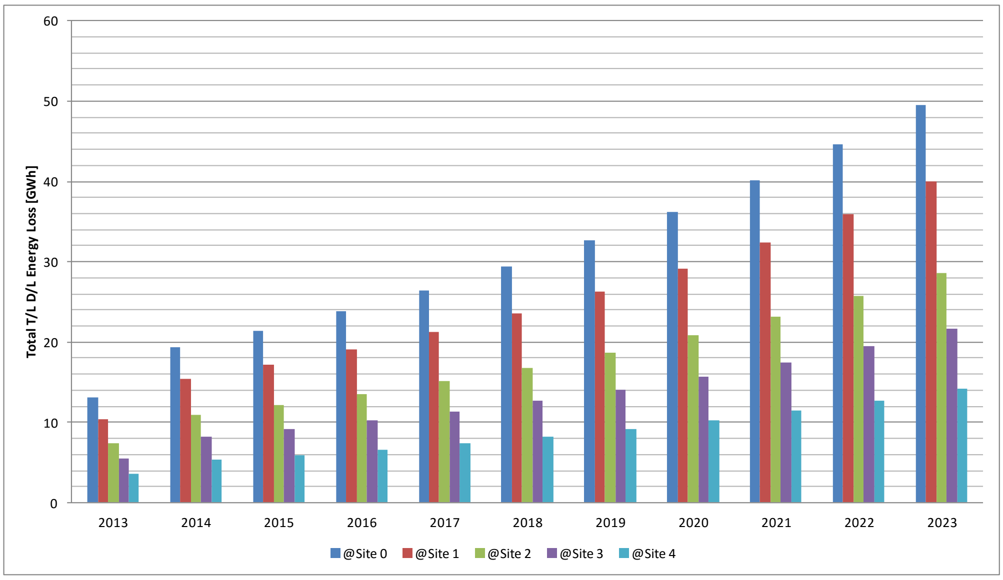


Transmission Line
Energy Loss
Max.: around 1.0GWh
(@ Site 4)

MV Distribution Line
Energy Loss
Max.: around 50GWh
(@ Site 0)

Source: JICA Study Team

Figure 6.2-11 Transmission / Distribution Losses Changes for each Candicate Site

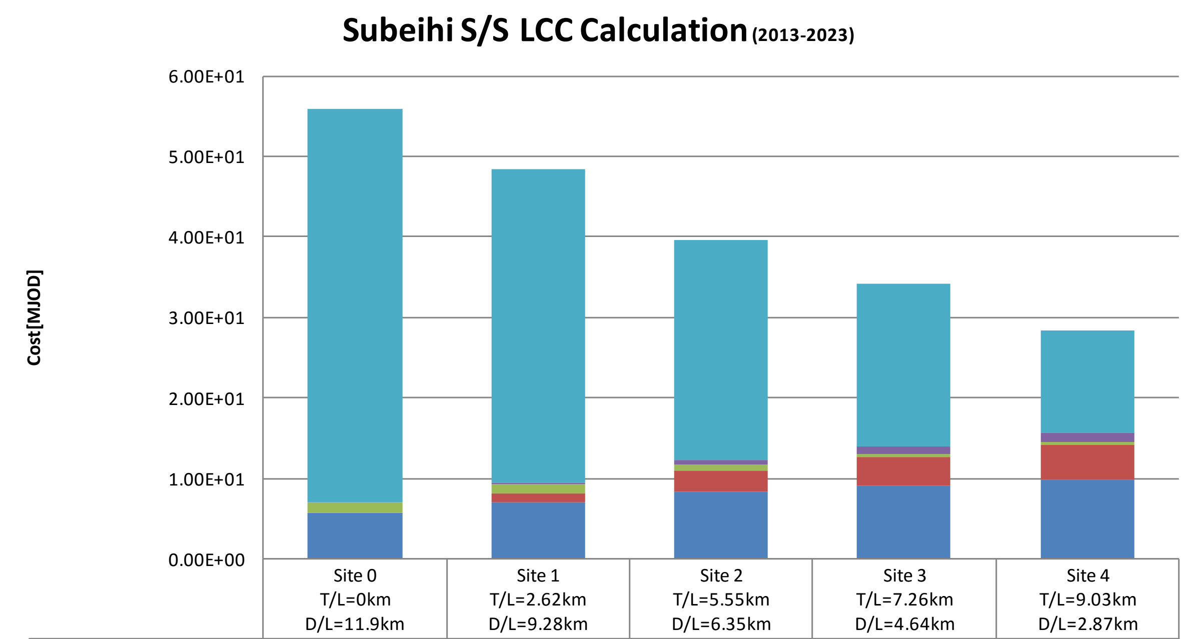


Total T/L & D/L Energy Loss
Site 0 Energy Loss is around 3.5 times of Site 4 one.

Source: JICA Study Team

Figure 6.2-12 Total of Transmission / Distribution Losses for each Candidate Site

In the next stage, LCC for each site was compared. Figure 6.2-13 shows the LCC for each site. According to Figure 6.2-13, the dominant factor of LCC is distribution losses. Therefore, the distribution losses minimized plan is positioned as the best solution for overall Electricity Sector at Subeihi S/S case.



	Site 0 T/L=0km D/L=11.9km	Site 1 T/L=2.62km D/L=9.28km	Site 2 T/L=5.55km D/L=6.35km	Site 3 T/L=7.26km D/L=4.64km	Site 4 T/L=9.03km D/L=2.87km
D/L Loss Damage [MJOD]	4.88E+01	3.90E+01	2.74E+01	2.03E+01	1.27E+01
T/L Loss Damage [MJOD]	0.00E+00	3.06E-01	6.49E-01	8.50E-01	1.06E+00
D/L Const [MJOD]	1.25E+00	9.75E-01	6.67E-01	4.87E-01	3.01E-01
T/L Const. [MJOD]	0.00E+00	1.26E+00	2.66E+00	3.49E+00	4.34E+00
BSP Const. [MJOD]	5.77E+00	6.95E+00	8.28E+00	9.06E+00	9.86E+00

Source: JICA Study Team

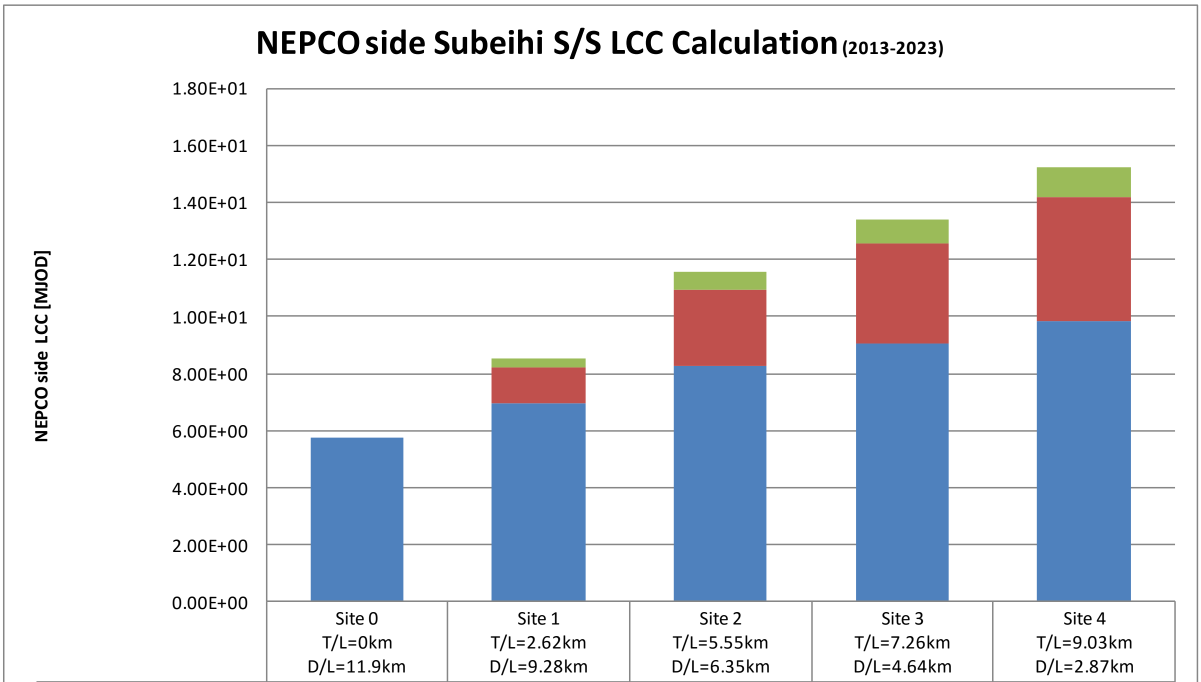
Figure 6.2-13 LCC Comparison of each candidate site

However, following two issues are identified from Figure 6.2-13.

- ➢ According to the calculation results of Site 4, the construction cost for transmission line and BSP is nearly equal to the economical damage by distribution losses when the BSP is located to minimize distribution losses. This fact says that the domination relationship of each cost item will be varied in the low load area.
- ➢ The plan for only minimizing distribution losses will make unfair situation between NEPCO and distribution companies because NEPCO shall invest all of increasing cost items.

The first issue is solved by sufficiently accurate LCC calculation using the result of carefully calculated demand forecast. This case shows the solutions are sometimes different each other between distribution losses minimization and overall electricity sector optimization.

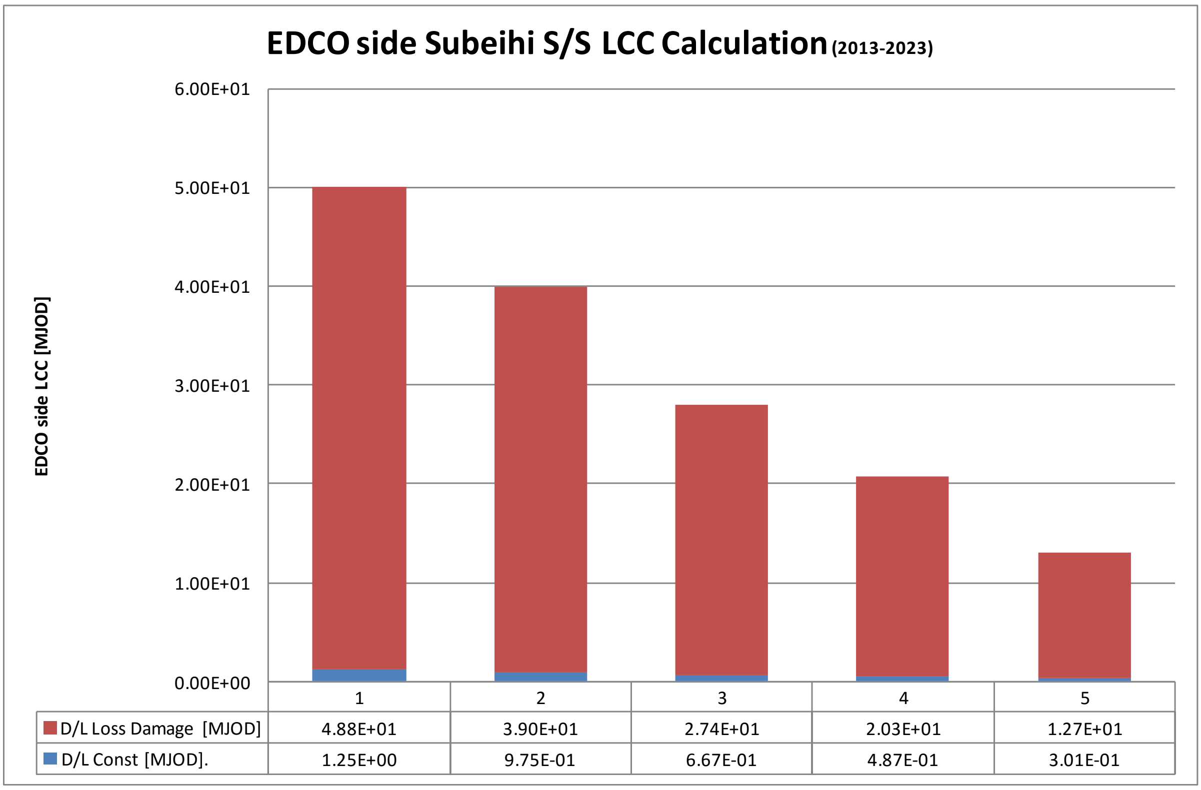
The second issue was studied in detail. Figure 6.2-14 shows the changing of NEPCO side LCC, and Figure 6.2-15 shows the changing of EDCO side LCC. In the case of Subeihi S/S, NEPCO side outgoing grows to twice by present scheme to realize the economical optimization for overall Electricity Sector. On the other hand, EDCO side LCC reduces around 75%, also the hierarchical relationship of each company's LCC is changed. Although NEPCO and distribution companies always share the basic policy that is to toward the economically optimization of overall Electricity Sector, this case shows there are some difficult cases to realize the policy by each side economical situation.



	Site 0 T/L=0km D/L=11.9km	Site 1 T/L=2.62km D/L=9.28km	Site 2 T/L=5.55km D/L=6.35km	Site 3 T/L=7.26km D/L=4.64km	Site 4 T/L=9.03km D/L=2.87km
T/L Loss Damage [MJOD]	0.00E+00	3.06E-01	6.49E-01	8.50E-01	1.06E+00
T/L Const. [MJOD]	0.00E+00	1.26E+00	2.66E+00	3.49E+00	4.34E+00
BSP Const. [MJOD]	5.77E+00	6.95E+00	8.28E+00	9.06E+00	9.86E+00

Source: JICA Study Team

Figure 6.2-14 NEPCO Side LCC Changing



Source: JICA Study Team

Figure 6.2-15 EDCO Side LCC Changing

(3) **Alternatives for Cost Sharing of BSP Construction**

This subsection shows some alternatives of latter issue in (2).

NEPCO shall spend all BSP construction cost in present scheme. According to the result of (2), NEPCO will not be able to accept the LCC optimization measure because all of increasing cost items shall be spent by NEPCO based on present scheme of investment for BSP e.g. shown in Table 6.2-25.

Table 6.2-25 Cost Impact Analysis of BSP Location Optimization

Item	Present (Site 0 may be selected)		Proposed (Site 4 will be selected)		Present–Proposed	
	NEPCO [MJOD]	DIstribution company [MJOD]	NEPCO [MJOD]	DIstribution company [MJOD]	NEPCO [MJOD]	Distribution company [MJOD]
BSP Construction	5.77	0	9.86	0	▲4.09	0
T/L Construction	0	0	4.34	0	▲4.34	0
D/L Construction	0	1.25	0	0.301	0	0.949
T/L Loss	0	0	1.06	0	▲1.06	0
D/L Loss	0	48.8	0	12.7	0	36.1
Total	5.77	50.1	15.1	13.0	▲9.48	37.0

Source: JICA Study Team

This mean, all of cost items spent by NEPCO shown in following are increased by minimizing of large economical impact item i.e. distribution losses, that is, allocating the BSP near by load center.

- BSP construction cost: Increase land acquisition cost → Cost increasing
- Transmission line construction cost: Increase the length of transmission line between BSP and existing transmission line → Cost increasing
- Transmission losses: Increase the impedance of transmission line because of extension of the line → Cost increasing

As well as all of cost item spent by distribution companies will be decreased as following.

- Distribution losses: Be smaller the impedance of distribution line because of shortening of the line → Cost reducing
- Distribution line construction cost: Be shorter the length of distribution line between BSP and new load → Cost reducing

Therefore, it will be hard to realize the planning measure of LCC optimization under the agreement between NEPCO and distribution companies because the cost conditions are different. To solve this problem, spending the BSP construction cost partially by distribution companies i.e. equalizing the cost condition will be preferable. Five alternatives for sharing of BSP construction cost are shown in following. Recommendable executing measure is selecting the best alternatives by an agreement through discussion about the calculation results of all five alternatives because the best alternative will be varied by each case.

(i) **Alternative 1: Equalization of increased / decreased balance by shifting of BSP location to optimal position**

According to the case shown in Table 6.2-25, the balance of each company will be as follows at present scheme.

- NEPCO: 9.48[MJOD] loss
- Distribution company: 37.0[MJOD] surplus
- Overall Electricity Sector: 27.6[MJOD] surplus

Although there are loss case and surplus case, total balance of overall Electricity Sector is surplus. If the surplus is equalized, it will be easier to make an agreement for executing the optimal BSP planning measure even if the surplus of distribution companies will be reduced because both companies will gain the profit more than present scheme.

To equalize the surplus for each company, total surplus of overall Electricity Sector 27.6[MJOD] is devided by 2 and distribute it to each company like as following.

- NEPCO: 13.8[MJOD] surplus
- Distribution company: 13.8[MJOD] surplus
- Overall electricity sector: 27.6[MJOD] surplus

As a result, BSP construction cost is adjusted like as follows.

- BSP construction cost spent by distribution companies: 37.0[MJOD] –13.8[MJOD] =23.2[MJOD] → 9.86[MJOD]
- BSP construction cost spent by NEPCO: 9.86[MJOD] –9.86[MJOD] = 0.0[MJOD]

Although the balance was not equalized completely such as following because the calculated BSP construction cost spent by distribution companies beyond the original BSP construction cost, unfairness of cost condition will be improved partially.

- NEPCO: ▲9.48[MJOD] → 0.380[MJOD]: turned to surplus status
- Distribution companies: 37.0[MJOD] → 27.1[MJOD]: maintain surplus status

As a result, NEPCO will be able to cancel all of BSP construction cost, and distribution companies will be able to gain additional 23.0[MJOD] surplus compaired with Site 0.

(ii) **Alternative 2: Distribution companies spend only the increased cost by shifting of BSP location to optimal position**

As a result of executing BSP location optimization in case of Table 6.2-25, all increasing cost items are spent by NEPCO, and NEPCO shall pay 4.09[MJOD] additionally for only BSP construction. Alternative 2 proposes that distribution companies spend only the additional cost (4.09[MJOD]) as BSP construction cost.

(iii) **Alternative 3: Halve increased cost by shifting of BSP location to optimal position**

Alternative 3 proposes that dividing the loss of NEPCO side only for BSP construction (4.09[MJOD]), and distribution companies spend the divided cost (2.04[MJOD]: 20.7[%]) as BSP construction cost. Although the balance is not equalized because only additional cost is halved, it will assure tolerable equality because the loss is divided equally.

(iv) **Alternative 4: Equalize both company's LCC**

Alternative 1 to Alternative 3 focus on only the varied balance from present scheme. On the other hand, Alternative 4 proposes that both companies share completely equalized LCC.

- Differential of both company's LCC: 2.21[MJOD]
- Cost adjustment of higher LCC side (NEPCO): -1.10[MJOD]
- Cost adjustment of lower LCC side (distribution company.): +1.10[MJOD]
- BSP construction cost spent by NEPCO: 9.86[MJOD] -1.10[MJOD] =8.75 [MJOD] (88.8[%])
- BSP construction cost spent by distribution company: 1.10[MJOD] (11.2[%])
- NEPCO side adjusted LCC: 14.1[MJOD]
- Distribution companies side adjusted LCC: 14.1[MJOD]

Although this alternative is fairest sharing method from long term viewing, Alternative 2 and 3 should also be considered simultaneously to consider some constraints for each case.

(v) **Alternative 5: Sharing rate decided by the Score**

Alternative 5 proposes that the cost sharing rate is decided by the differential of following two scored items when alternative 1 to 4 couldn't make an agreement.

- Necessity of BSP construction as Electricity Sector (N)
- Properties of distribution company side benefit by construction of BSP (B)

Table 6.2-26 Score Definition of Necessity of BSP construction as Electricity Sector (N)

No.	Properties	Point (N)
1	The new loads can be supplied Power from near existing BSP, and the BSP doesn't have to be reinforced to conforming to future demand.	1
2	The BSP has enough capacity now, but the capacity will be short in the future.	2
3	Now new BSP shall be installed to recover Power supply ablity immediately.	3

Source: JICA Study Team

Table 6.2-27 Score Definition of Properties of Distribution Company side benefit by construction of BSP (B)

No.	Properties	Point (B)
1	To supply new loads area.	1
2	BSP shall be installed, but enough distribution company side benefit will be assured.	2
3	No need to install new BSP	3

Source: JICA Study Team

The difference of there is positioned as indicator.

$$\mathrm{Index\_BSP} = \mathrm{N} - \mathrm{B}$$

Index_BSP can be from −2 to +2. In case Index_B is higher, the significance of BSP construction will be higher. Vice versa Index_B is lower, the significance of BSP construction will be lower. Therefore, cost share rate can be defined as Table 6.2-28. It is recommendable that the share rate list and score definition shown as Table 6.2-27 and Table 6.2-28 should be changed to conform with each situation.

Table 6.2-28 Share Rate List of BSP Construction Cost for Alternative 5

Index_BSP	Priority as Electricity Sector	Share Rate	
		Distribution Company.	NEPCO
＋2	Highest Priority	0 %	100 %
＋1	Higher Priority	5 %	95 %
±0	Normal Priority	10 %	90 %
－1	Lower Priority	30 %	70 %
－2	Lowest Priority	50 %	50 %

Source: JICA Study Team

6.3 Power System Planning

6.3.1 Power System Plan in NEPCO

In NEPCO, renewable energy and oil-shale power plants are planned by 2018 and the related transmission projects are ongoing or planned. Table 6.3-1 shows the power system plan in NEPCO. By the EIB and AFD finance, the green corridor projects are ongoing. The 400kV transmission will be doubled by this project.

In the power system planning in the 2008 master plan study, there are power flow analysis, short-curcuit analysis, stability analysis etc. in substation planning, transmission planning and interconnection planning. But recently, the master plan is not prepared.

Table 6.3-1 Power system plans by 2018 in NEPCO

Project	Year	Point of Connection	Line Length	Line type
Amman West Grid Connection	2016			
Samra-Amman West 400kV OHL (70 km)		Double circuits	70km	400kV OHTL Triple
Qatraneh-Amman West 400kV OHL (130 km)		Double circuit	130km	400kV OHTL Triple
Amman West Substation 132kV connection with Swemeh 132kV OHL		Double circuit	35km	132kV OHTL
Amman West Substation 132kV connection with Salt		Double circuit	15km	132kV Superheated 1.5
Amman West Substation		2 transformers 400 MVA. 11= CB 132kV 9= CB 400kV 4 Reactors	-	-
Project	**Year**	**Details**		**Region**
BSPs (Substations) Expansion	2016			
Safawi Substation Expansion 132kV (external)		Adding one 10MVA transformer		Mafraq
Rweshid Substation Expansion 132kV (external)		Adding one 10MVA transformer		Mafraq
Waqas Substation Expansion 132 kV (external)		Adding one 63MVA transformer		Ajloun
Salt Substation Expansion		Adding one 80MVA transformer		Balqa'a
New Zarqa Substation	2017	3= transformers 132/33kv with capacity 80MVA each 9 = 132kv CB 6= Reactors 23 = 33kV CB		Zarqa
Project	**Year**	**Point of Connection**	**Line Length**	**Line type**
Oil Shale connection	2017			
400kV Switching Station for Oil Shale Project connection allajoun		Double circuit in-out To Qatrana 400/132 kV substation	10km	400kV OHTL
Oil Shale Project connection Attarat		With Amman east	106km	400kV OHTL
		With Amman south	92km	400kV OHTL

Project	Year	Point of Connection	Line Length	Line type
ACWA Project connection	2017			
132kV Switching Station for ACWA Project connection		Existing HTPS 132/33kV	-	-
Samra- HTPS		Open	12km	
Samra - HTPS		Reconductering double circuits	6.35km	132kV superheated 1.5
Project	Year	Point of Connection	Line Length	Line type
Replacement of Conductors for Samra-Rajhi-Rehab OHLs	2018	Samra-rehab	28.7km	132kV superheated 1.5
		Samra-rajihi	24km	
		RAJHI-REHAB (1)	24km	
DELENOVA Wind Project Connection		Double circuit from ishtafina S/S	12km	132kV OHTL
Project	Year	Point of Connection	Line Length	Line type
Green Corridor Project	2018			
Hasa-Tafila Reconductering		Double circuits	40km	132kV superheated 1.5
Hasa-Qatrana Reconductering		Single circuit	43.925km	132kV superheated 1.5
Hasa-Qatrana Cement Reconductering		Single circuit	47.6km	132kV superheated 1.5
Qatrana- Qatrana Cement Reconductering		Single circuit	7.3km	132kV superheated 1.5
Replacement of Conductors for Fujaij-Ma'an 132kV OHLs		Double circuits	50km	132kV superheated 1.5
Double Circuit OHLs for Ma'an - (in-Out joint) - New Ma'an		Double circuits	3km	132kV superheated 1.5
QAIA Substation Expansion (Green Corridor Project)		Double circuit QAIA-Qatrana	60km	132kV OHTL
Green corridor connected wind farms	2018			
King Hussain Wind Project Connection		Single line open in Fujaij-Ma'an 132kV	5km	132kV OHTL
Rajif Wind Farm		In/out Qwera-Ma’an 48km from Qwera		132kV OHTL
Tafila Wind Substation		In/Out Hasa – RASHADIA 7 KM From HASA		
KOSPO Wind Project Connection		3.5km Double circuit from Tafila WF	3.5km	132kV OHTL
XENEL Wind Project Connection		3.5km Double circuit from kospo 7km from Tafila WF	7km	132kV OHTL
400Kv Grid Reinforcement	2016			
Qatraneh 400kV Line		Qatrana- New Ma’an	150km	400kV OHTL
QAIA Substation Expansion (Green Corridor Project)		Adding two CB 132kV	Amman	
Qatraneh Substation Expansion(Green Corridor Project)		Adding two CB 132kV	Karak	
Qatraneh 400kV Substation Expansion (connection with Ma'an 400kV) Green Corridor Project)	2018	Adding two of (one and half CB) each 400kV	Karak	
Ma'an 400/132/33kV Substation (Green Corridor Project)		2018 Two Transformers 400MVA	Ma'an	

Source : NEPCO

6.3.2 Issues on the Power System in NEPCO

JICA study team received the current power system of PSS/E data from NEPCO and prepared the PSS/E data in 2018 together with NEPCO.

Table 6.3-2 and Figure 6.3-1 show the issues on the power system in 2018. There are several 132kV transmission lines that do not observe N-1 standard. And there are some substations where the single line to ground fault current exceeds its breaking capacity of circuit breakers such as Qatrana and Tareq.

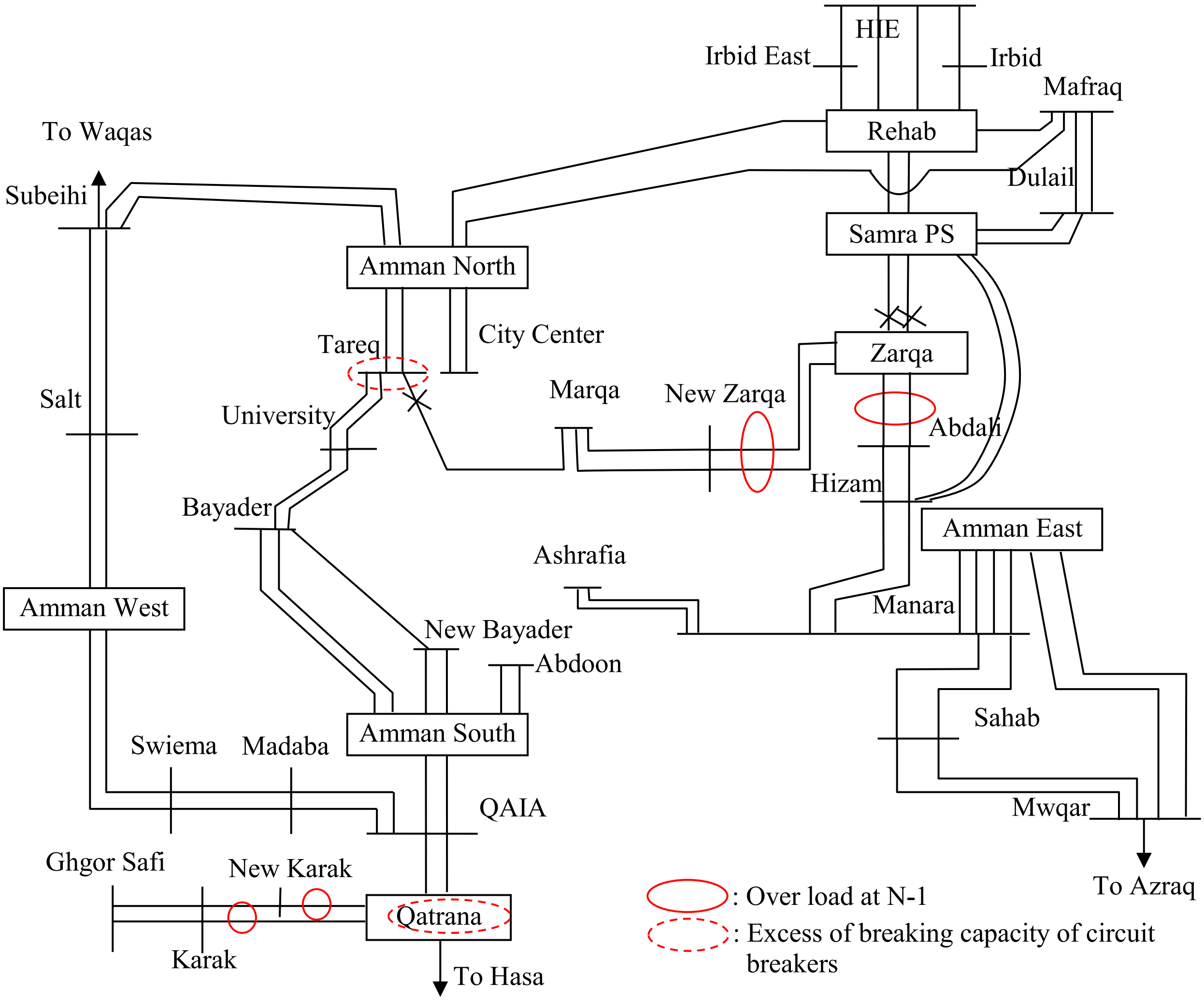
Table 6.3-3 and Figure 6.3-2 show the measures for the issues in 2018. To reduce the fault level at Qatrana and Tareq, system separations and 132kV system connection changes are considered.

Table 6.3-4 shows the power generation balance used in the PSS/E analysis. Table 6.3-5 shows cost list provided by NEPCO.

Table 6.3-2 Issues on the power system in 2018

High Loading 132kV Transmission lines	HTPS to Abdali 111% (N-1) HTPS to Zarqa New 107% (N-1) Qatrana to Karak 113% (N-1) Qatrana to South Karak 109% (N-1)
Opreating Rate of the 400kV Substations	-
Voltage drop	South Karak 0.91pu (N-1) Ghorsafi 0.91pu (N-1) Karak 0.93pu (N-1)
Single line to ground fault current (Short-circuit current)	Qatrana 33.8kA (27.9kA) Tareq 33.5kA (27.2kA) Amman South 30.1kA (27.2kA) HTPS 27.2kA (22.7kA)

Source: JICA Study Team



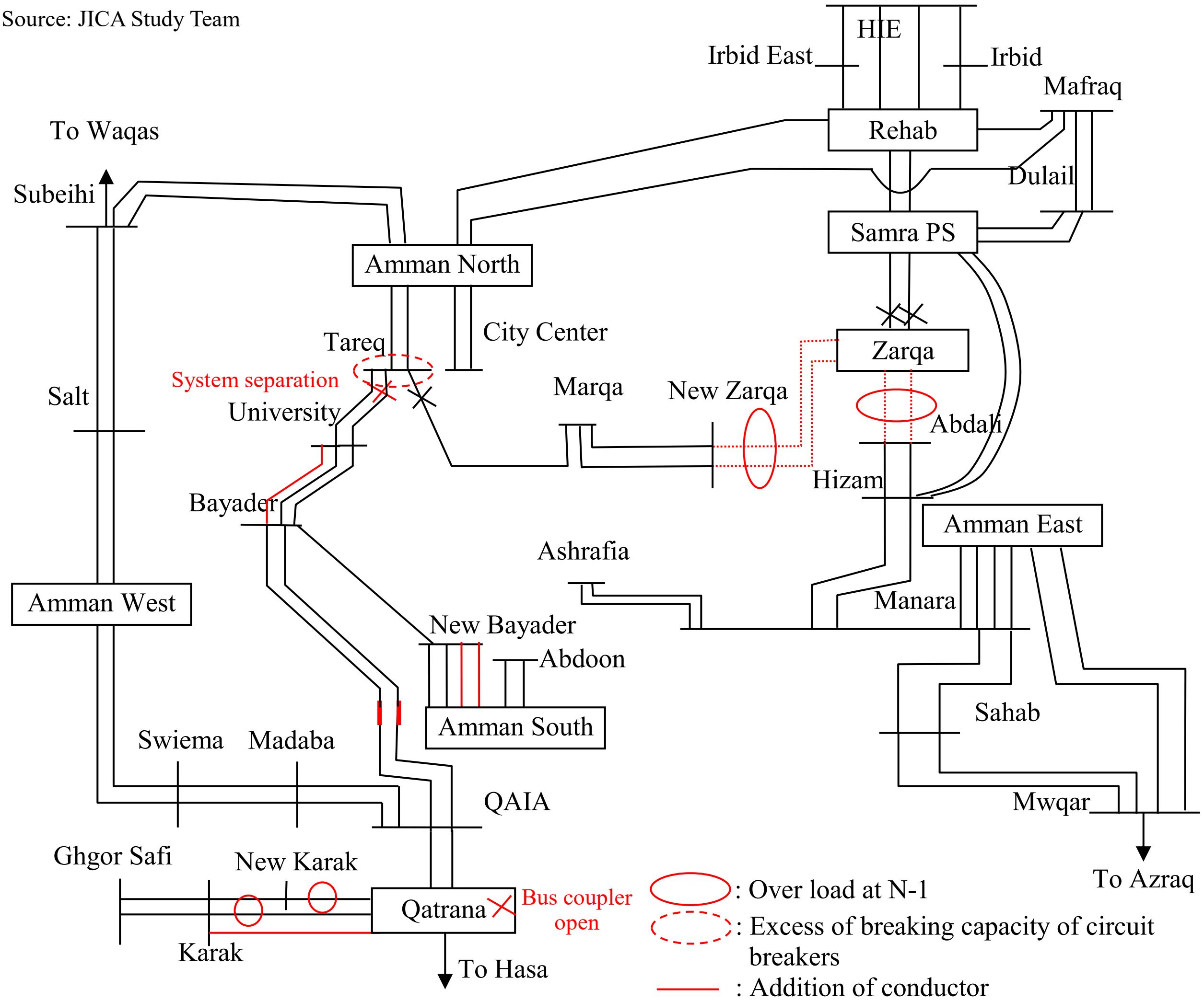
Source: JICA Study Team

Figure 6.3-1 Issues on the 132kV power system in 2018

Table 6.3-3　Measures for the issues on the power system in 2018

Measures	
Reinforcement for High Loading 132kV Transmission line	Replacing to Superheated conductor -HTPS to Abdali -HTPS to Zarqa New Addition of conductor -Qatrana to Karak
Reinforcement for High fault current level (Measures accompanied by the changing of system configuration at Amman South)	Addition of conductor -Amman South to New Bayader, double circuit -Bayader to university
After measures	
Single line to ground fault current (Short-circuit current)	Qatrana 21.0kA (25.2kA) Tareq 21.2kA (19.1kA) HTPS 19.5kA (15.2kA) Amman South 28.7kA (23.6kA)

Source: JICA Study Team



Source: JICA Study Team

Figure 6.3-2　Measures for the Issues on the 132kV power system in 2018

Table 6.3-4 Power generation balance used in the PSS/E analysis

Base Scenario Base1(Nuclear:No delay) (MW)

Power Plant	Unit	rated output	Bus name/Substation	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
				Capacity																			
ATPS	ST 1	137	ATPS_G1	121	121	121	130	0															
ATPS	ST 2	137	ATPS_G2	121	121	121	130	90															
ATPS	ST 3	137	ATPS_G3	121	121	121	130	130	130	130	130	130	130	0	0	0	0	0	0				
ATPS	ST 4	137	ATPS_G4	121	121	121	130	130	130	130	130	130	130	0	0	0	0	0	0				
ATPS	ST 5	137	ATPS_G5	121	121	121	130	130	130	130	130	130	130	0	0	0	0	0	0				
HTPS	ST 4			48																			
HTPS	ST 5			48																			
HTPS	ST 7			48																			
Risha	GT 1	30	RESHA_GT1	25	25																		
Risha	GT 2	30	RESH_GT2	25	25																		
Risha	GT 3	30	RESHA_GT3	25																			
Risha	GT 4	30	RESHA_GT4	25	25																		
Risha	GT 5	30	RESHA_GT5	25	25	25	30	30	30	30	30	30	30	0	0	0	0	0	0				
Rehab	GT 10	30	REHAB_GT10	26	26	26																	
Rehab	GT 11	30	REHAB_GT11	26	26	26	20	20															
Rehab	CC	285	REHAB_GT12, GT13, ST	260	260	260	225	270	270	270	270	270	270	0									
Rehab	CC	450	REHAB CC N						450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Amman South	GT 9	60	AS_GT1, GT2	26	26																		
Samra	I	351	SAMRA_GT1, GT2, ST1	270	270	270	300	300	300	300	300	300	300	0	0	0	0	0	0	0	0	0	
Samra	II	351	SAMRA_GT3, GT4, ST2	270	270	270	300	300	300	300	300	300	300	0	0	0	0	0	0	0	0	0	0
Samra	III	435	SAMRA_GT5, GT6, ST3	400	400	400	390	390	390	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Samra GT7	IV			145	145	145	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130	130
Samra ST4	IV						70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
IPP 1, Amman East	CC	420	AME_GT1,GT2,ST1	360	360	360	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390
IPP 2, Qatrana	GT/CC	411	QAT_GT1,GT2,ST	360	360	360	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
IPP 3	DE	588	IPP3_11~72	573	573	573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IPP 4	DE	320	AE_IPP4_1,2,3,4	241	241	241	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACWA	CC	510	ACWA_GT1,GT2,GT3,ST1			315	450	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510	510
CCGT 2027	CC	450	Hasan?													450	450	450	450	450	450	450	450
CCGT 2029	CC	450	QAIA?															450	450	450	450	450	450
CCGT 2030	CC	450	?																450	450	450	450	450
CCGT 2032	CC	450	?																		450	450	450
CCGT 2033	CC	450	?																			450	450
CCGT 2034	CC	450	?																				450
OSPP 1(Attrat)	Oil Shale	235	ATTRAT OS					235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
OSPP 2(Attrat)	Oil Shale	235	ATTRAT OS					235	235	235	235	235	235	235	235	235	235	235	235	235	235	235	235
OSPP3	Oil Shale																						
OSPP4	Oil Shale																						
OSPP5	Oil Shale																						
NPP	Nuclear											1,000	1,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Wind	TAFILA W	117	TAFILA132 W	117	117	117	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0
	HussainWind	80	HUSSAIN W/MAAN NEW			80	61	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
	RAJIF Wind	83	RAJIF WIND P			83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
	FAJIJ Wind	90	FAJIJ W			90	70	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
	KOSPO Wind	50	KOSPO WIND			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	XENEL Wind	50	XENEL WIND			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	Assumption cap		TFILA 132 W					24	49	75	104	134	166	200	236	277	320	366	416	469	525	585	650
Solar	MDA PV	162	MDA PV		162	162	136	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162
	Jo Solar PV	20	JO SOLAR PV/HIE		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	SHAMSUNA	10	SHAMSUNA PV/AQABA TH		7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
	SCATEC Solar	10	SCATEC PV/MAAN		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Mafraq PV	150	Mafraq PV/Mafraq				150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
	QUWIRA PV	100	QWIRA PV				60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
	SAFAWI PV	50	SAFAWI PV				50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	Assumption cap		MAAN					25	51	78	107	137	170	205	242	284	329	377	428	482	540	602	668
Total Capacity(MW)				3,948	3,978	4,545	4,382	4,730	5,121	5,184	5,242	6,302	6,367	6,146	6,219	6,171	6,840	7,384	7,935	8,042	8,606	9,178	9,759
Peak Demand(MW)				3,323	3,501	3,658	3,840	4,032	4,234	4,446	4,674	4,911	5,167	5,440	5,725	6,050	6,398	6,769	7,166	7,588	8,040	8,521	9,037

Source: JICA Study Team

Table 6.3-5 Unit costs used for analysis and costing of developments

Item	Unit	Cost US$(000s)
Location		
Land cost - Amman new site	1	6,808
Land cost - Amman extension	1	2,723
Land cost - Other new site	1	2,723
Land cost - Other extension	1	1,362
Bays		
400kV Bay AIS	1	1,340
132kV Bay GIS	1	1,058
132kV Bay AIS	1	257
33kV Bay	1	71
Transformaer		
400MVA 400/132kV Transformer	1	4,230
240MVA 400/132kV Transformer	1	2,820
110MVA 132/33kV Transformer	1	1,734
80MVA 132/33kV Transformer	1	6,345
63MVA 132/33kV Transformer	1	4,583
45MVA 132/33kV Transformer	1	409
16MVA 132/33kV Transformer	1	353
10MVA 132/33kV Transformer	1	317
Overhead lines		
400kV 3 x 560mm ACSR/ACS OHL	DC km	423
400kV 2 x 560mm ACSR/ACS OHL	DC km	395
132kV 2 x 400mm ACSR OHL	DC km	300
132kV 1 x 400mm AAAC OHL	DC km	254
132kV 1 x 400mm ACSR OHL	DC km	250
132kV 1 x 400mm ACSR OHL	SC km	150
132kV 1 x 240mm ACSR OHL	SC km	100
132kV Drake ACSS HTLS	DC km	450
132kV ACSS 450 or 425/55mm HTLS (Conductor and Replacement)	SC km	113
Underground cables		
132kV 1 x 1000mm Cu XLPE Cable double	DC km	2,000
132kV 1 x 1000mm Cu XLPE Cable	DC km	1,692
132kV 1 x 1000mm Cu XLPE Cable	SC km	1,300
132kV 1 x 500mm Cu XLPE Cable	SC km	1,021
33kV 500mm Al XLPE Cable	SC km	96
Compensation equipment		
33kV Capacitor Bank - 4 x 10MVAR	1	600
33kV Capacitor Bank - 1 x 20MVAR	1	71
33kV Capacitor Bank - 4 x 7.5MVAR	1	550
11kV Capacitor Bank - 12MVAR	1	87

DC; Double Circuits, SC; Single Circuit

Source: NEPCO

6.3.3 Power system planning for generation development plans

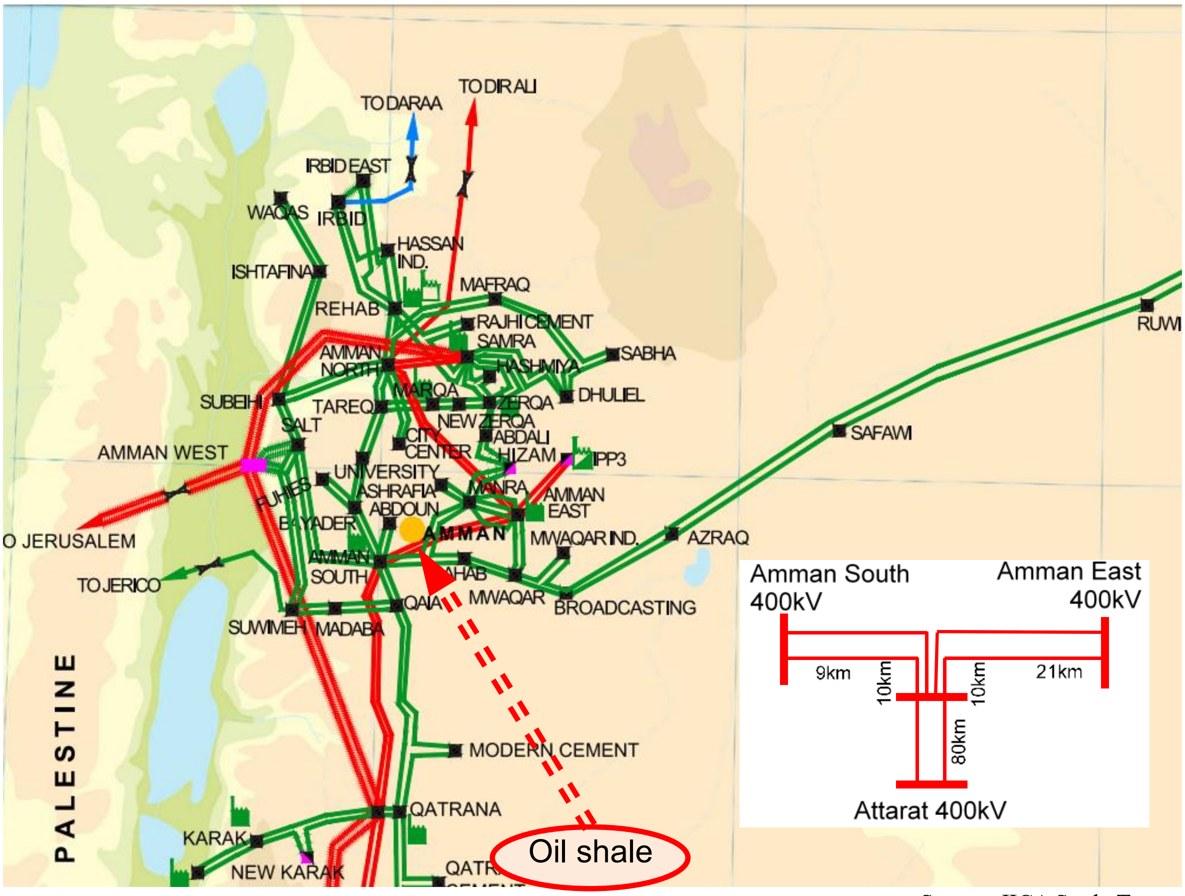
1) Oil-shale power generation in Attarat in 2019

The following three connection plans for the Attarat oil-shale power generation in 2019 using PSS/E are analyzed and checked in terms of overloading of substations and transmission lines, system voltage and single line to ground fault current. And construction cost is estimated using the unit cost as shown in Table 6.3-5.

- ✓ Connection plan 1: 400kV Amman South T/L and Amman East T/L
- ✓ Connection plan 2: 132kV QAIA Substation
- ✓ Connection plan 3: 400kV New Qatrana Substation

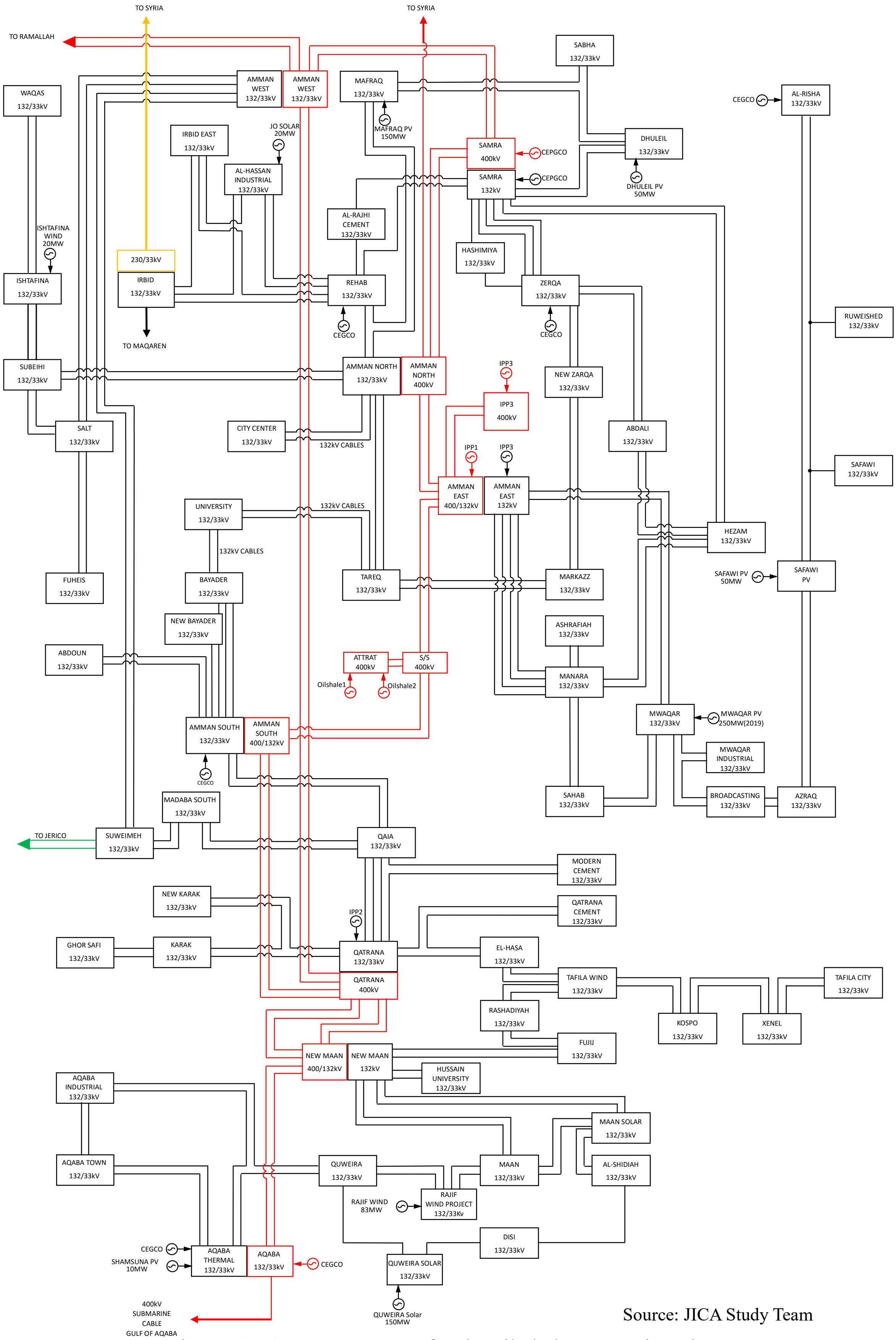
(i) Oil-shale connection plan 1

Figure 6.3-3 shows power system connection with the Attarat oil-shale power generation plan 1. Figure 6.3-4 shows the power system diagram. Table 6.3-6 shows the analysis result. This plan is needed the reinforcement of 132kV transmission lines and 400kV transmission line between Aqaba to New Ma'an and Amman South substation.



Source: JICA Study Team

Figure 6.3-3 Oil-shale connection plan 1 (400kV Amman South T/L and Amman East T/L)



Source: JICA Study Team

Figure 6.3-4　Power system for the oil-shale connection plan 1

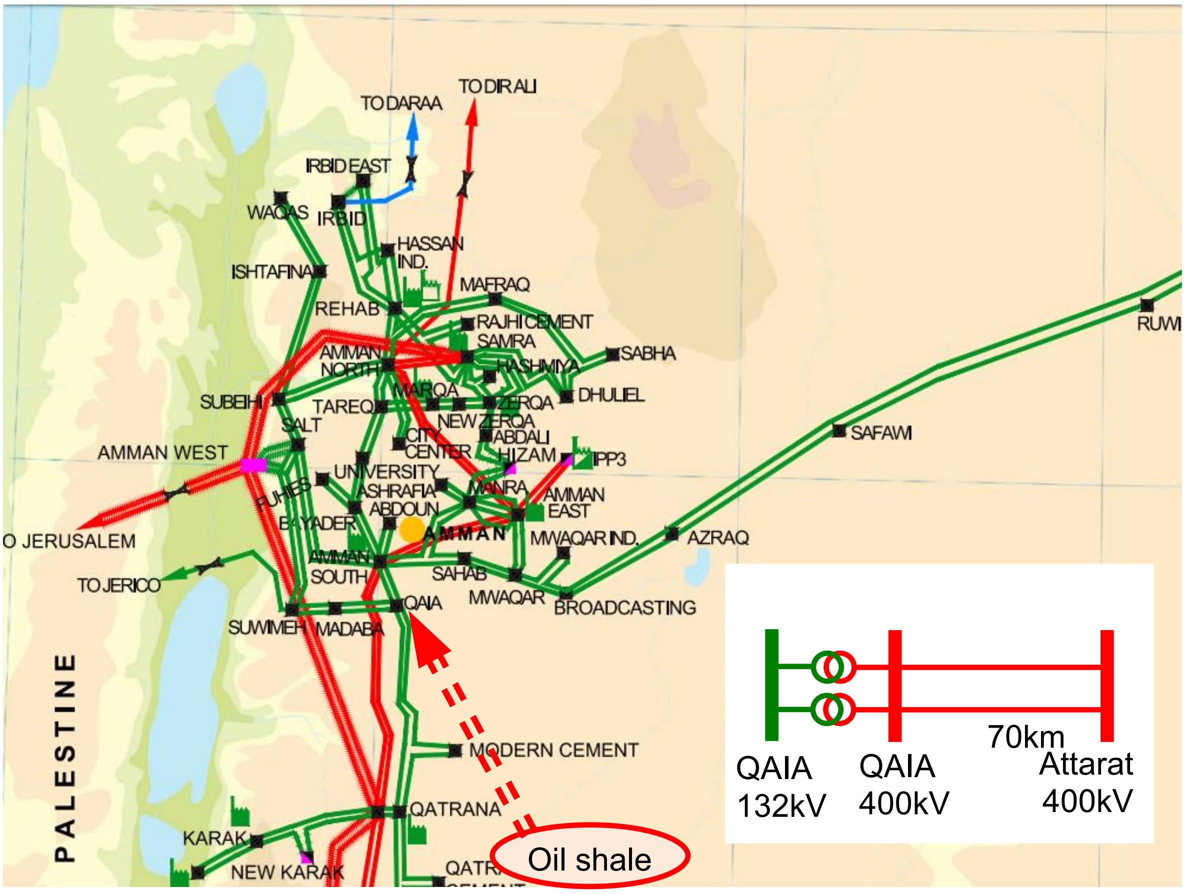
Table 6.3-6 Analysis result for oilshale power generation plan 1 in 2019

Item	From		To	
132kV transmission line loading in N-1 state	Amman South	-	Bayader	147%
	Bayader	-	University	122%
	Rehab	-	Samra	115%
400kV transmission line loading in N-1 state	Aqaba	-	New Ma'an	111%
400kV substation loading in N-1 state	Amman South			183%
Single line to ground fault current	Tareq			18.7kA
	Amman South main			17.0kA
	Amman South reserve			25.9kA
	Qatrana main			24.9kA
	Qatrana reserve			12.9kA
Cost	Construction cost			47,540 thousand USD
	Related reinforcement cost			70,293 thousand USD
	Total			117,833 thousand USD

Source: JICA Study Team

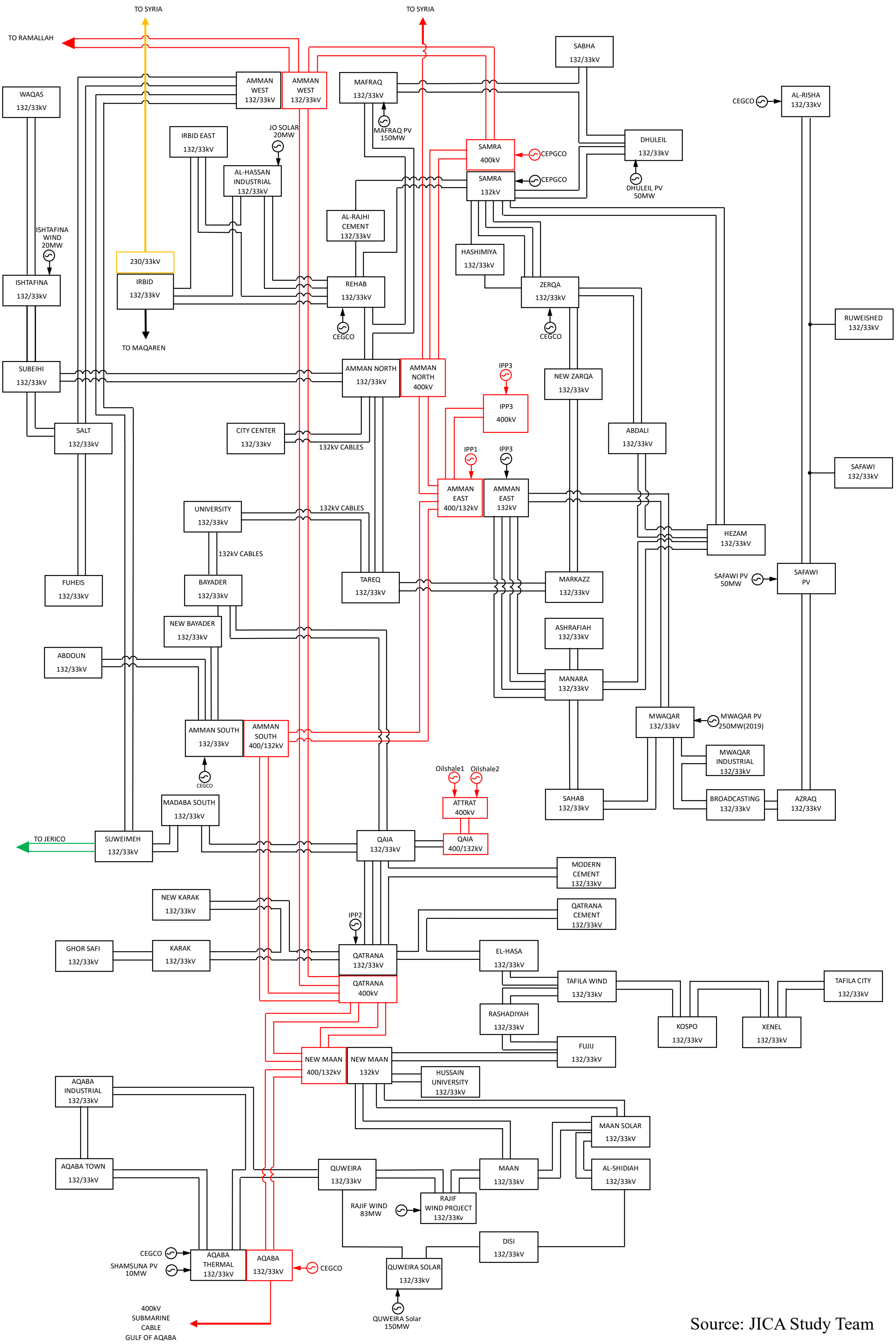
(ii) Oil-shale connection plan 2

Figure 6.3-5 shows power system connection with the Attarat oil-shale power generation plan2. Figure 6.3-6 show the power system diagram. Table 6.3-7 shows the analysis result. As for this plan, it is necessary to change the transmission route around Amman South substation. However, the cost of the connection plan 2 is the lowest cost among three connection plans.



Source: JICA Study Team

Figure 6.3-5 Oil-shale connection plan 2 (132kV QAIA Substation)



Source: JICA Study Team

Figure 6.3-6 Power system for the oil-shale connection plan 2

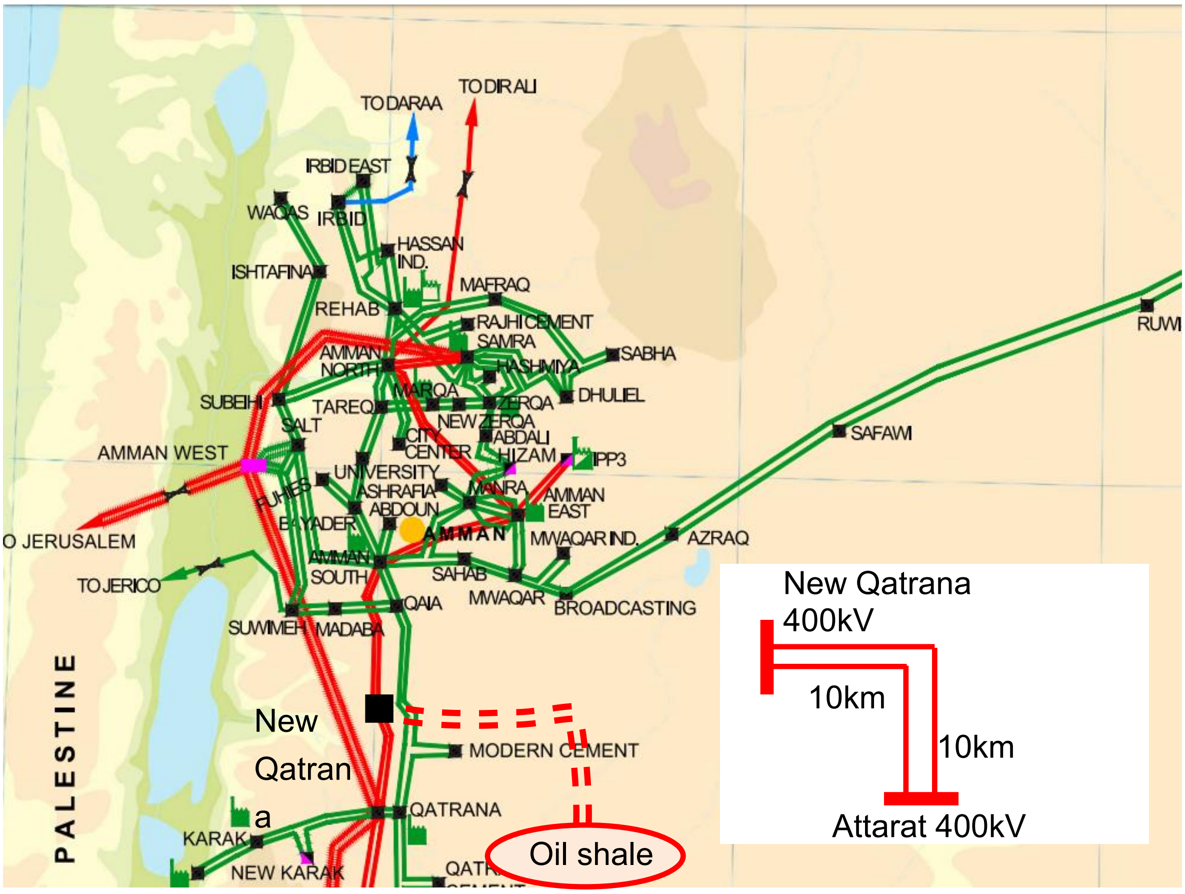
Table 6.3-7 Analysis result for oilshale power generation plan 2 in 2019

Item	From		To	
132kV transmission line loading in N-1 state	Amman South	-	Bayader	-
	Bayader	-	University	-
	Rehab	-	Samra	107%
400kV transmission line loading in N-1 state	Aqaba	-	New Ma'an	-
400kV substation loading in N-1 state	Amman South			-
Single line to ground fault current	Tareq			27.9kA
	Amman South main			25.2kA
	Amman South reserve			25.2kA
	Qatrana main			25.2kA
	Qatrana reserve			12.0kA
Cost	Construction cost			40,152 thousand USD
	Related reinforcement cost			55,200 thousand USD
	Total			95,352 thousand USD

Source: JICA Study Team

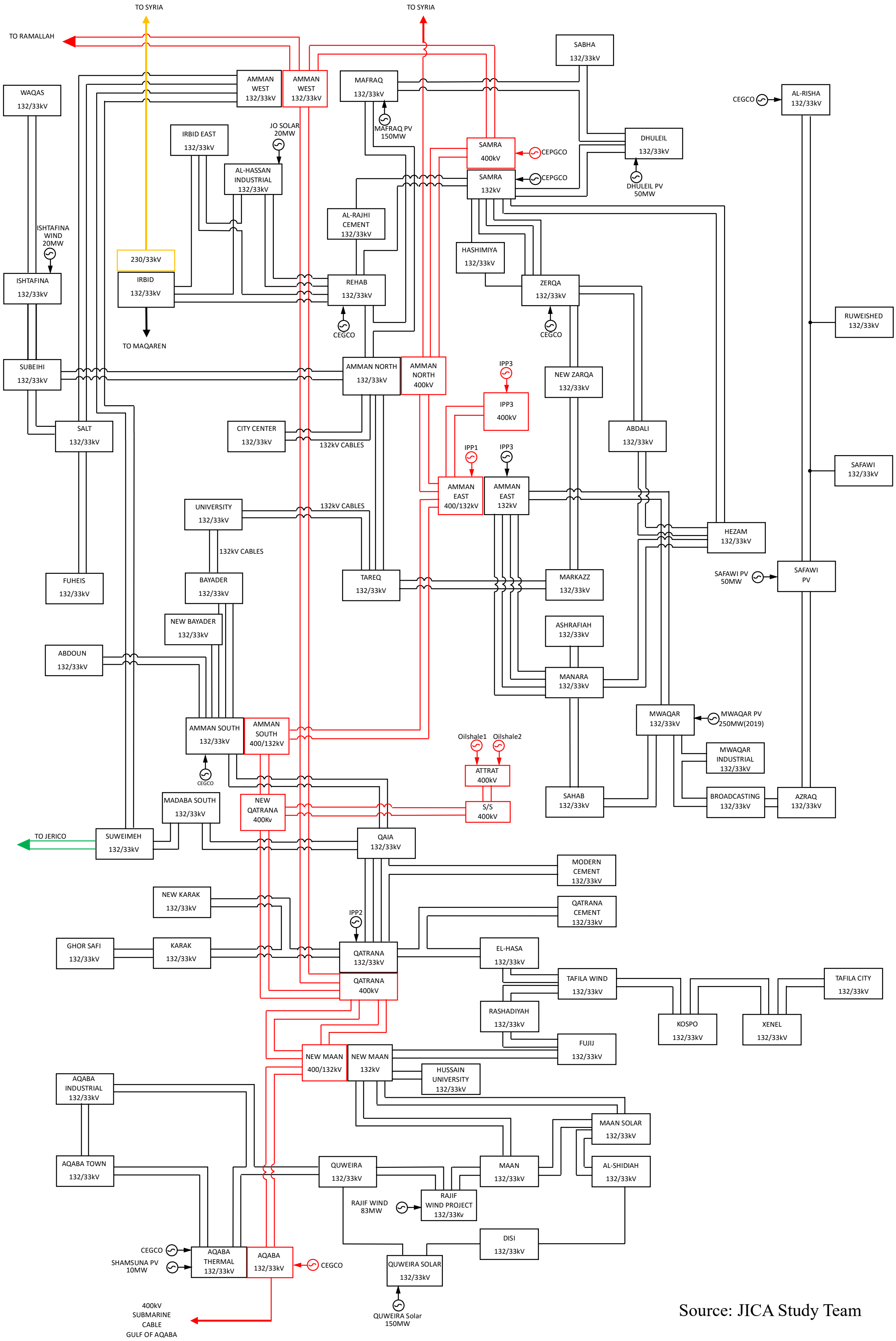
(iii) Oil-shale connection plan 3

Figure 6.3-7 shows power system connection with the Attarat oil-shale power generation plan 3. Figure 6.3-8 shows the power system diagram.Table 6.3-8 shows the analysis result. This plan needs the reinforcement of 132kV transmission lines and 400kV transmission line between Aqaba to New Ma'an and Amman South substation. This connection plan is the most expensive among three plans.



Source: JICA Study Team

Figure 6.3-7 Oil-shale connection plan 3 (400kV New Qatrana Substation)



Source: JICA Study Team

Figure 6.3-8 Power system for the oil-shale connection plan 3

Table 6.3-8 Analysis result for oilshale power generation plan 3 in 2019

Item	From		To	
132kV transmission line loading in N-1 state	Amman South	-	Bayader	119%
	Bayader	-	University	127%
	Rehab	-	Samra	102%
400kV transmission line loading in N-1 state	Aqaba	-	New Ma'an	108%
400kV substation loading in N-1 state	Amman South			135%
Single line to ground fault current	Tareq			16.3kA
	Amman South main			21.7kA
	Amman South reserve			21.8kA
	Qatrana main			24.6kA
	Qatrana reserve			12.1kA
Cost	Construction cost			19,223 thousand USD
	Related reinforcement cost			99,128 thousand USD
	Total			118,351 thousand USD

Source: JICA Study Team

2) Nuclear Power Generation near Azraq in 2025

Four connections plans for the nuclear power generation have been studied in combination with four connection plans for the Attrat Oil-shale power generation in 2025 using PSS/E and checked in terms of overloading of substations and transmission lines, system voltage and single line to ground fault current, transient stability analysis for nuclear transmission line fault and overloading on substations and transmission lines in N-2 status of nuclear traismission lines. And construction cost are estimated using the unit cost as shown in Table 6.3-5.

- ✓ Connection plan 1: 400kV New HIE Substation and 400kV Amman East Substation
- ✓ Connection plan 2: 400kV New HIE Substation and 400kV New Qatrana Substation
- ✓ Connection plan 3: 400kV New HIE Substation and 400kV Samra Substation
- ✓ Connection plan 4: 400kV New HIE Substation and 400kV New QAIA Substation

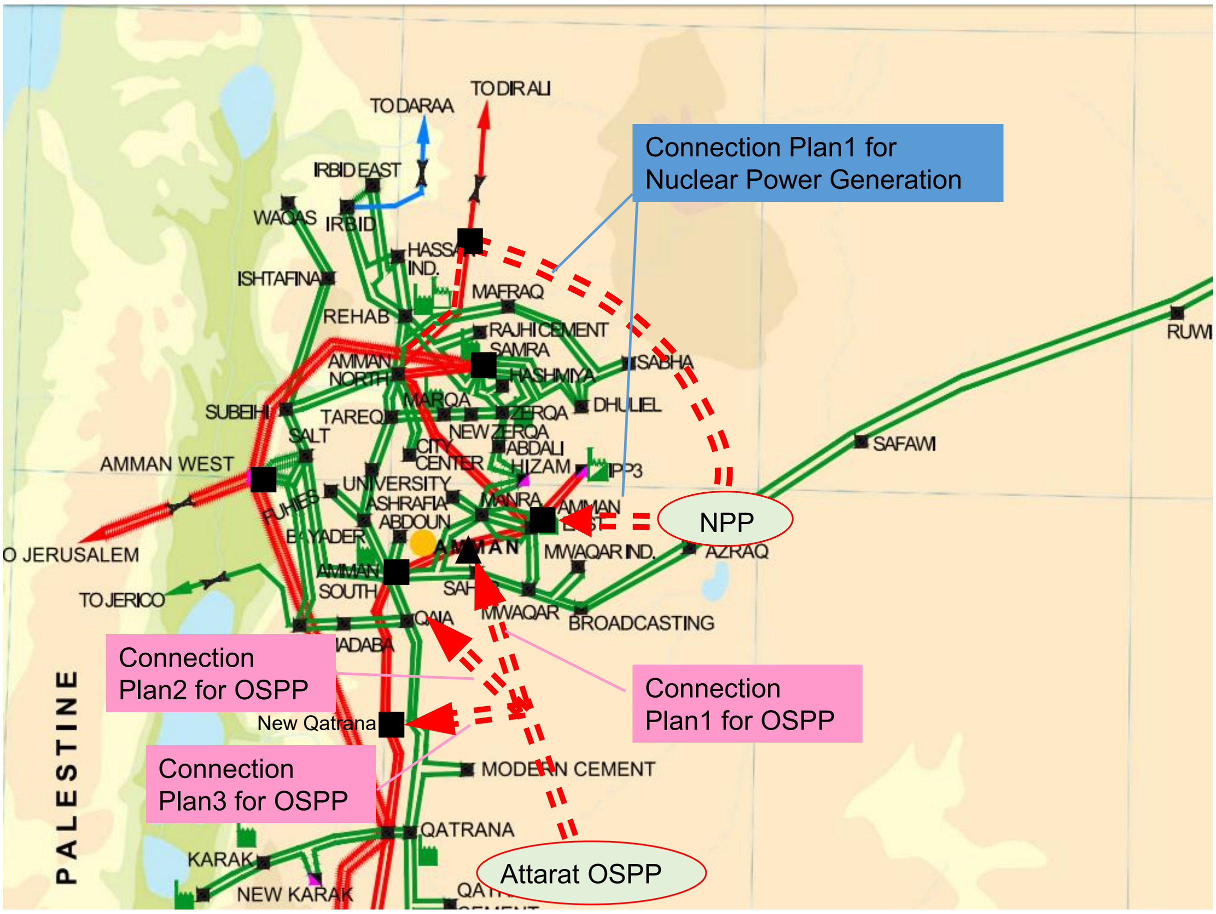
Table 6.3-9 Study scenario for nuclear power generation in combination with the Attrat Oil-shale power generation

Study Scenarios	Nuclear power generation	Oil-shale power generation
1-1	Plan 1: 400kV New HIE Substation and 400kV Amman East Substation	Plan 1: 400kV Amman South and Amman East T/L
1-2		Plan 2: 132kV QAIA Substation
1-3		Plan 3: 400kV New Qatrana Substation
2-1	Plan2: 400kV New HIE Substation and 400kV New Qatrana Substation	Plan 1: 400kV Amman South and Amman East T/L
2-2		Plan 2: 132kV QAIA Substation
2-3		Plan3: 400kV New Qatrana Substation
3-1	Plan3: 400kV New HIE Substation and 400kV Samra Substation	Plan 1: 400kV Amman South and Amman East T/L
3-2		Plan 2: 132kV QAIA Substation
3-3		Plan3: 400kV New Qatrana Substation
4	Plan 4: 400kV New HIE Substation and 400kV New QAIA Substation	Plan 4: 400kV New QAIA Substation

Source: JICA Study Team

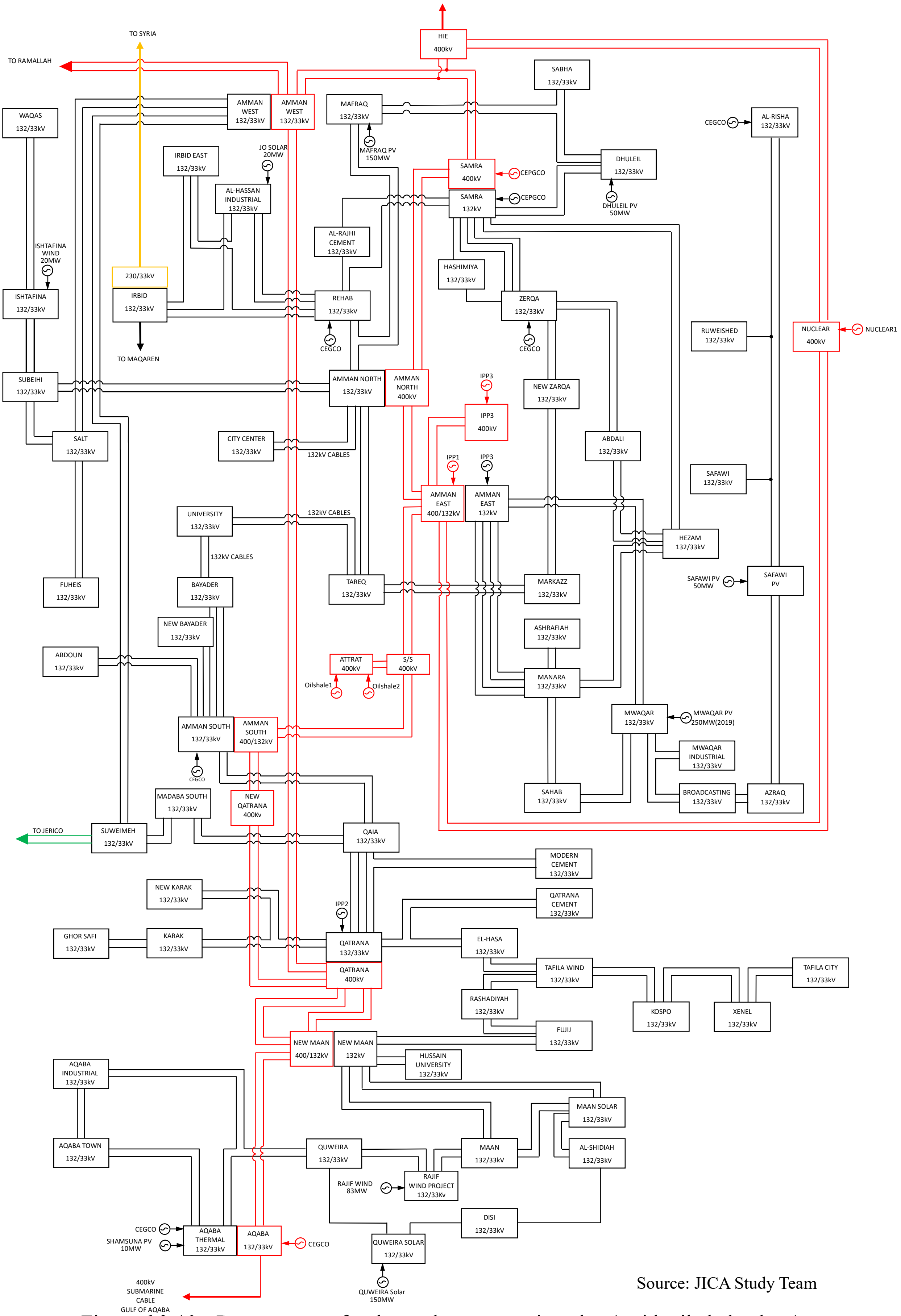
(i) Nuclear connection plan 1 & Oil-shale connection plan 1-3

Figure 6.3-9 shows power system connection with the nuclear power generation (plan1) and the Attarat oil-shale power generation (plan1-3). Figure 6.3-10 shows the power system diagram with Attrata oil-shale power generation plan 1. Table 6.3-10 shows the analysis result. However, The Amman East substation is unsuited as a nuclear connection point in security. Because power generations and transmission lines are concentrated.



Source: JICA Study Team

Figure 6.3-9 The nuclear power generation (plan1) and the Attarat oil-shale power plant (plan1)



Source: JICA Study Team

Figure 6.3-10 Power system for the nuclear connection plan 1 with oil-shale plan 1

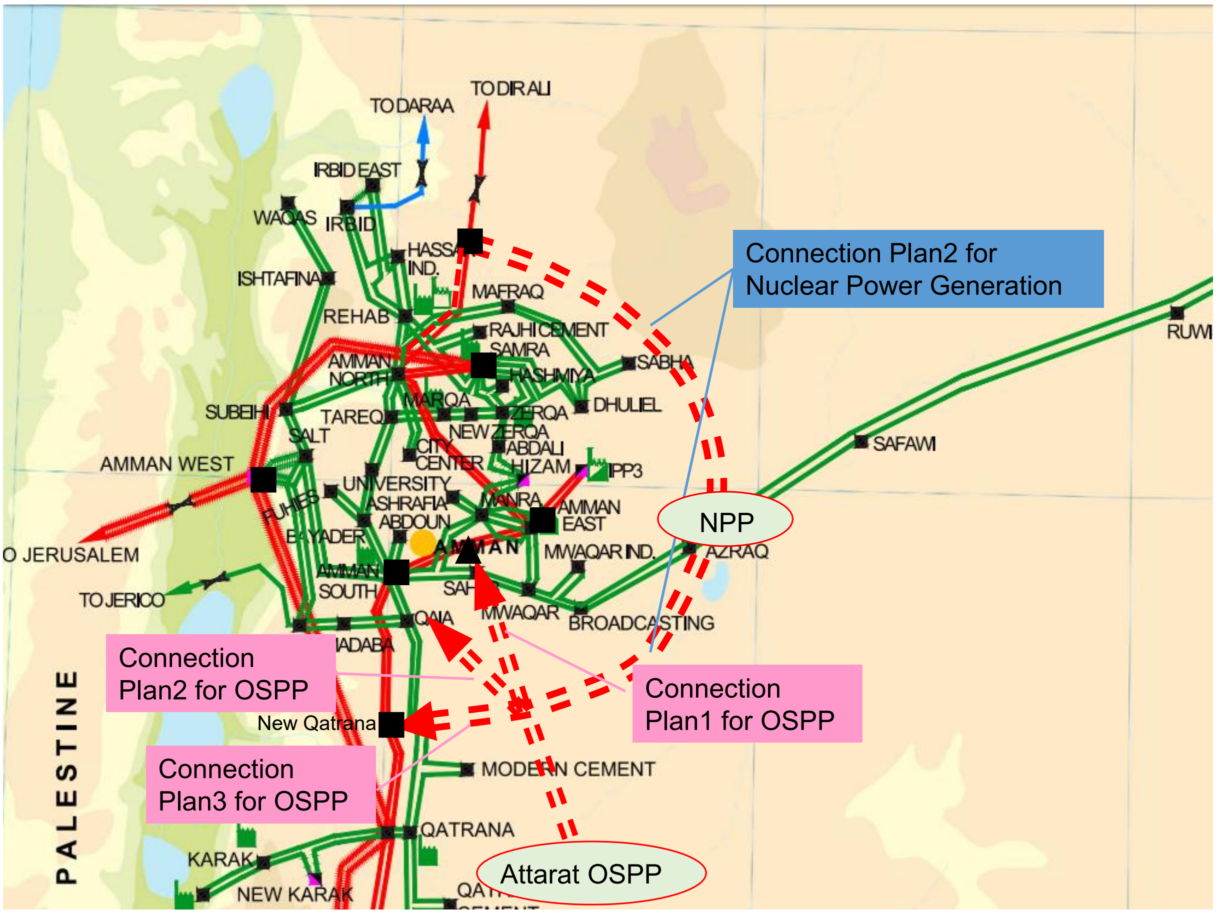
Table 6.3-10 Analysis result for Nuclear power generation plan 1 in 2025

Item	From		To	Study scenarios			
					1-1	1-2	1-3
				NPP	HIE, Amman East		
				OSPP	Amman South-Amman East	QAIA	New Qatrana
132kV transmission line loading in N-1 state	Hizam	-	Manara		103%	107%	102%
	Hizam	-	Abdali		159%	189%	189%
	Hizam	-	Samra		124%	127%	126%
	Bayader	-	Amman South		151%	150%	152%
	Marqa	-	Zarqa		140%	140%	140%
	HTPS	-	Zarqa		119%	119%	119%
	HIE	-	Hassan		-	-	-
	Manara	-	Amman South		116%	116%	116%
	Amman South	-	QAIA		-	-	-
	QAIA	-	Madaba		-	108%	-
400kV transmission line loading in N-1 sate	Samra	-	Amman North		-	-	-
400kV substation loading in N-1 state	Amman South				146%	-	143%
	Amman East				102%	102%	102%
	Amman North				106%	103%	105%
	Amman West				-	-	-
Single line to ground fault current	Amman South main				23.9kA	24.8kA	23.6kA
	Amman South reserve				24.1kA	23.9kA	24.0kA
	Tareq				20.9kA	20.8kA	20.9kA
	Qatrana main				23.9kA	24.7kA	23.9kA
	Qatrana reserve				13.4kA	13.4kA	13.5kA
	Amman East				30.9kA	30.5kA	30.7kA
	HTPS				18.5kA	18.5kA	18.5kA
Cost [1,000USD]	Construction cost for nuclear				98,369	98,369	98,369
	Related reinforcement cost				29,589	28,589	29,589
	Sub total				127,958	126,889	127,958
	Oilshale T/L cost				117,833	95,352	118,351
	Total				245,791	222,241	246,309

Source: JICA Study Team

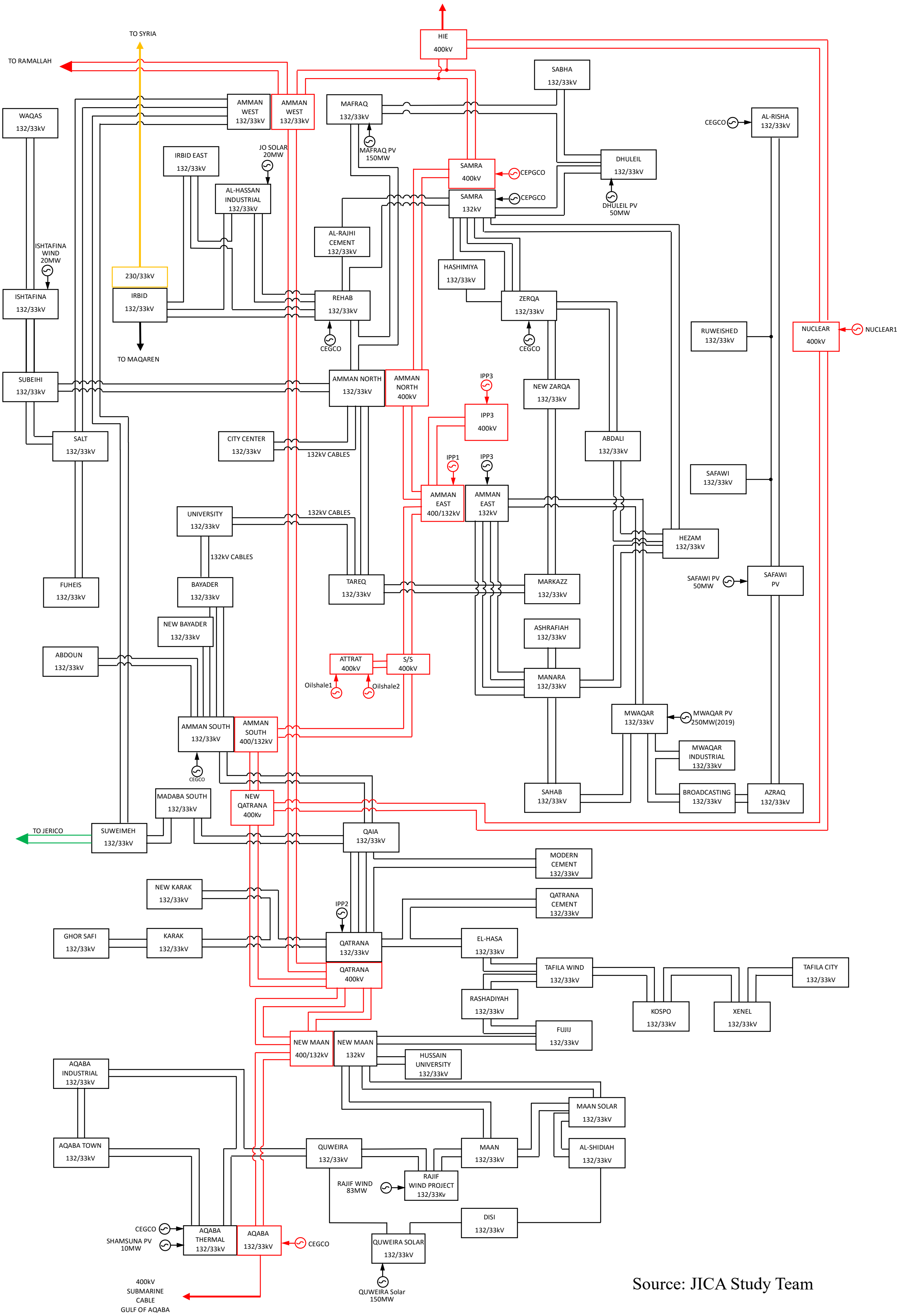
(ii) Nuclear connection plan 2 & Oil-shale connection plan 1-3

Figure 6.3-11 shows power system connection with the nuclear power generation (plan2) and the Attarat oil-shale power generation (plan1-3). Figure 6.3-12 shows the power system diagram with Attrata oil-shale power generation plan 1. Table 6.3-11 shows the analysis result. The total cost for New Qatrana substation connection scenario and Samra substation scenario are almost the same. This plan is easy to secure the place of new connection points such as HIE substation and New Qatrana substation with extension of the existing substation such as Amman East substation or Samra substation. For these reasons, the nuclear connection plan 2 was selected for study scenario after 2025 among connection plan 2-4 by discussion with NEPCO. And also, the oil-shale conection plan was selected for study scenario after 2025.



Source: JICA Study Team

Figure 6.3-11 Nuclear power generation (plan2) and the Attarat oil-shale power plant (plan1)



Source: JICA Study Team

Figure 6.3-12 Power system for the nuclear connection plan 2 with oil-shale plan 1

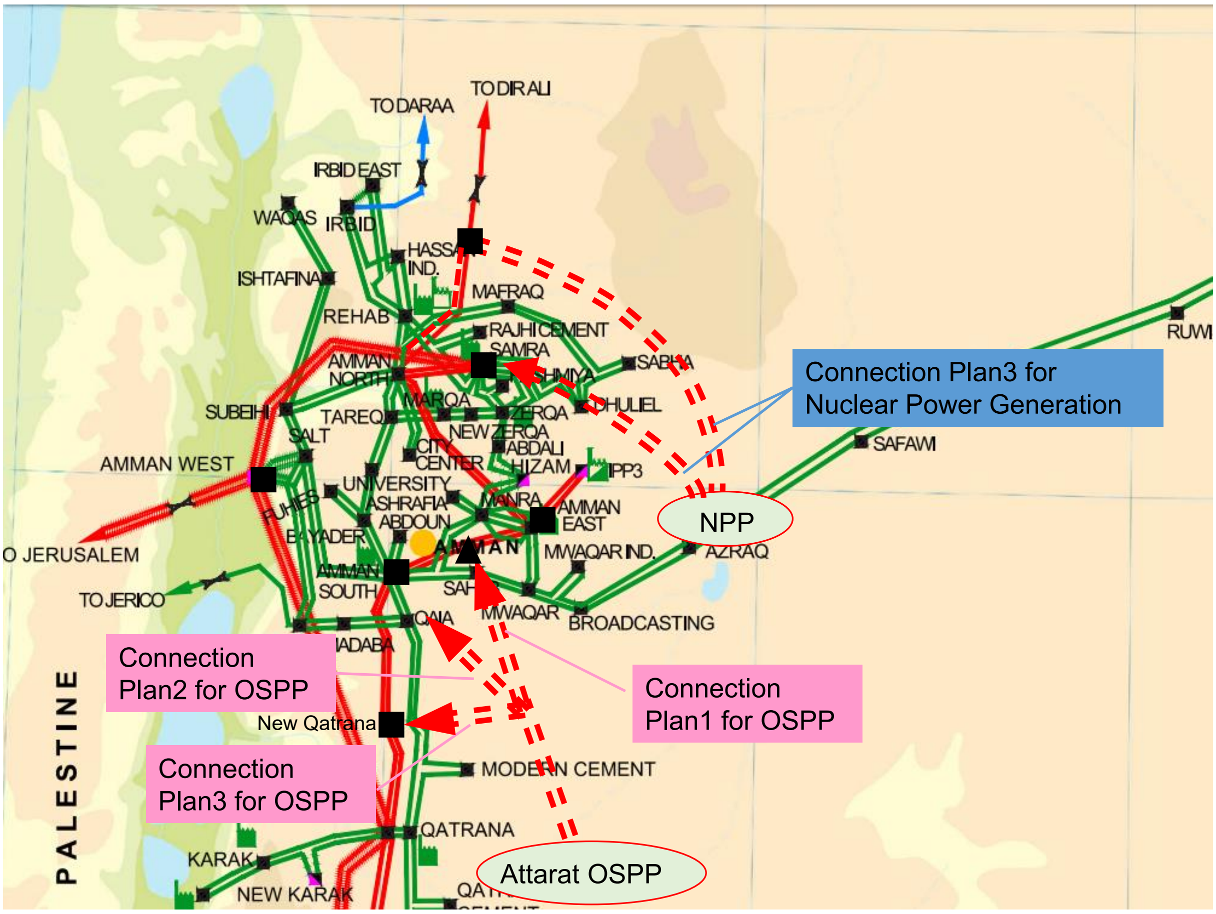
Table 6.3-11 Analysis result for Nuclear power generation plan 2 in 2025

Item	From		To	Study scenarios			
					2-1	2-2	2-3
				NPP	Amman East		
				OSPP	Amman South-Amman East	QAIA	New Qatrana
132kV transmission line loading in N-1 state	Hizam	-	Manara		-	-	-
	Hizam	-	Abdali		189%	189%	189%
	Hizam	-	Samra		131%	137%	137%
	Bayader	-	Amman South		151%	151%	153%
	Marqa	-	Zarqa		140%	140%	140%
	HTPS	-	Zarqa		119%	119%	119%
	HIE	-	Hassan		-	-	102%
	Manara	-	Amman South		116%	117%	117%
	Amman South	-	QAIA		-	103%	-
	QAIA	-	Madaba		-	109%	-
400kV transmission line loading in N-1 sate	Samra	-	Amman North		-	-	-
400kV substation loading in N-1 state	Amman South				140%	-	138%
	Amman East				-	-	-
	Amman North				-	-	-
	Amman West				-	-	101%
Single line to ground fault current	Amman South main				23.7kA	24.6kA	23.4kA
	Amman South reserve				23.6kA	23.3kA	23.4kA
	Tareq				20.7kA	20.6kA	20.6kA
	Qatrana main				24.1kA	25.0kA	24.1kA
	Qatrana reserve				13.6kA	13.6kA	13.6kA
	Amman East				29.8kA	29.3kA	29.5kA
	HTPS				18.5kA	18.5kA	18.5kA
Cost [1,000USD]	Construction cost for nuclear				117,780	117,780	113,550
	Related reinforcement cost				19,314	21,339	30,294
	Sub total				137,094	139,119	143,844
	Oilshale T/L cost				117,833	95,352	118,351
	Total				254,927	234,471	262,195

Source: JICA Study Team

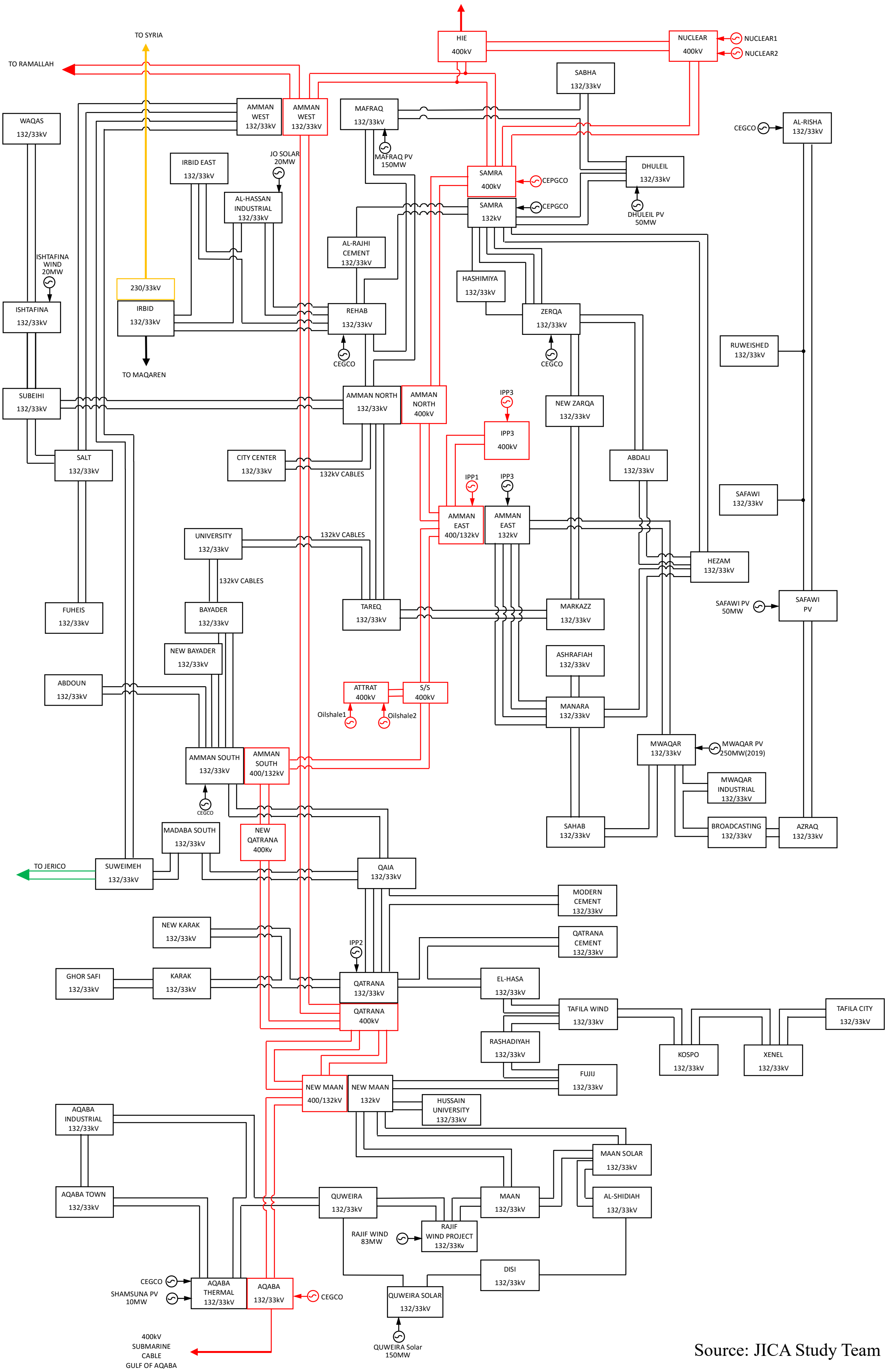
(iii) Nuclear connection plan 3 & Oil-shale connection plan 1-3

Figure 6.3-13 shows power system connection with the nuclear power generation (plan3) and the Attarat oil-shale power generation (plan1-3). Figure 6.3-14 shows the power system diagram with Attrata oil-shale power generation plan 1. Table 6.3-12 shows the analysis result. There is no much difference between the total cost for New Qatrana substation connection scenario and Samra substation scenario.



Source: JICA Study Team

Figure 6.3-13 Nuclear power generation (plan3) and the Attarat oil-shale power generation (plan3)



Source: JICA Study Team

Figure 6.3-14 Power system for the nuclear connection plan 3 with oil-shale plan 1

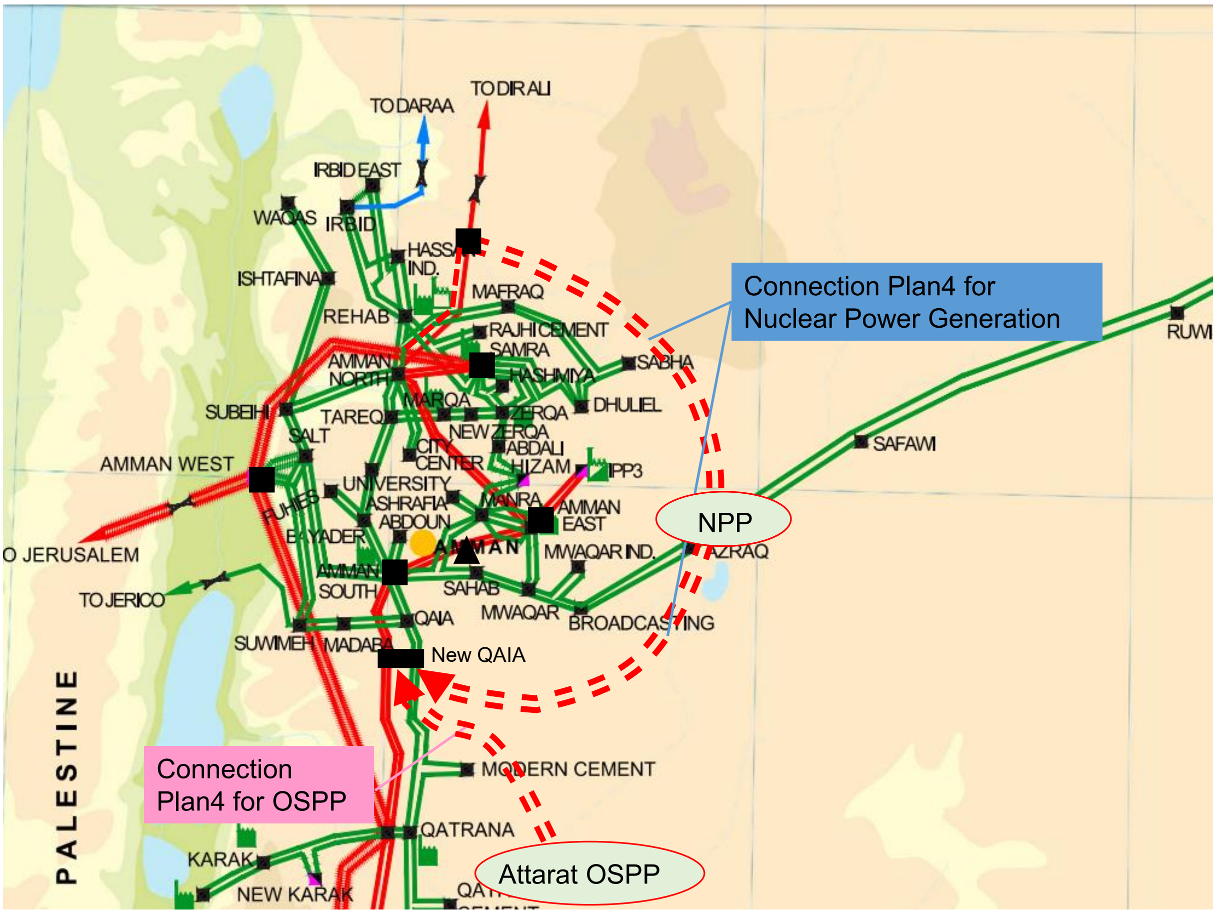
Table 6.3-12 Analysis result for Nuclear power generation plan 3 in 2025

Item	From		To	Study scenarios			
					3-1	3-2	3-3
				NPP	Amman East		
				OSPP	Amman South-Amman East	QAIA	New Qatrana
132kV transmission line loading in N-1 state	Hizam	-	Manara		-	-	-
	Hizam	-	Abdali		189%	189%	189%
	Hizam	-	Samra		142%	145%	144%
	Bayader	-	Amman South		152%	152%	153%
	Marqa	-	Zarqa		140%	140%	140%
	HTPS	-	Zarqa		119%	119%	119%
	HIE	-	Hassan		102%	102%	102%
	Manara	-	Amman South		117%	117%	117%
	Amman South	-	QAIA		-	103%	-
	QAIA	-	Madaba		-	-	-
400kV transmission line loading in N-1 sate	Samra	-	Amman North		110%	1115	110%
400kV substation loading in N-1 state	Amman South				142%	-	138%
	Amman East				-	-	-
	Amman North				103%	-	-
	Amman West				-	-	-
Single line to ground fault current	Amman South main				24.1kA	25.0kA	23.9kA
	Amman South reserve				24.4kA	24.1kA	24.2kA
	Tareq				22.0kA	21.9kA	21.9kA
	Qatrana main				24.3kA	25.3kA	24.4kA
	Qatrana reserve				13.5kA	13.4kA	13.5kA
	Amman East				30.8kA	30.4kA	30.7kA
	HTPS				18.8kA	18.8kA	18.8kA
Cost [1,000USD]	Construction cost for nuclear				102,599	102,599	102,599
	Related reinforcement cost				41,354	35,989	37,124
	Sub total				143,953	138,588	139,723
	Oilshale T/L cost				117,833	95,352	118,351
	Total				261,786	233,939	258,074

Source: JICA Study Team

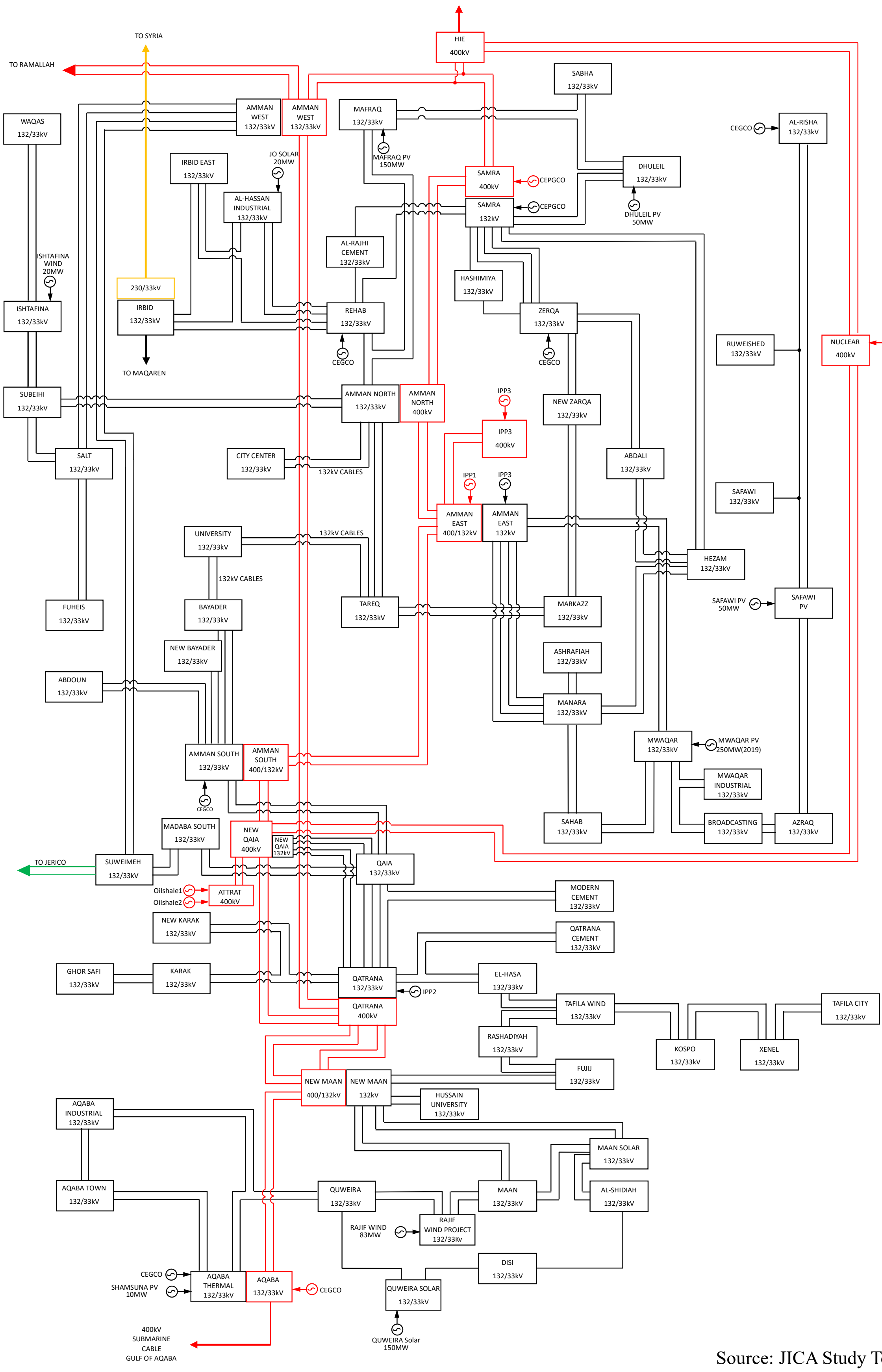
(iv) Nuclear & Oil-shale connection plan 4

Figure 6.3-15 shows power system connection with the nuclear power generation and the Attarat oil-shale power generation (plan 4). Figure 6.3-16 shows the power system diagram with Attrata oil-shale power generation plan 1. Table 6.3-13 shows the analysis result.



Source: JICA Study Team

Figure 6.3-15　Nuclear power generation and the Attarat oil-shale power generation (plan 4)



Source: JICA Study Team

Figure 6.3-16 Power system for the nuclear connection plan 4 with oil-shale plan 4

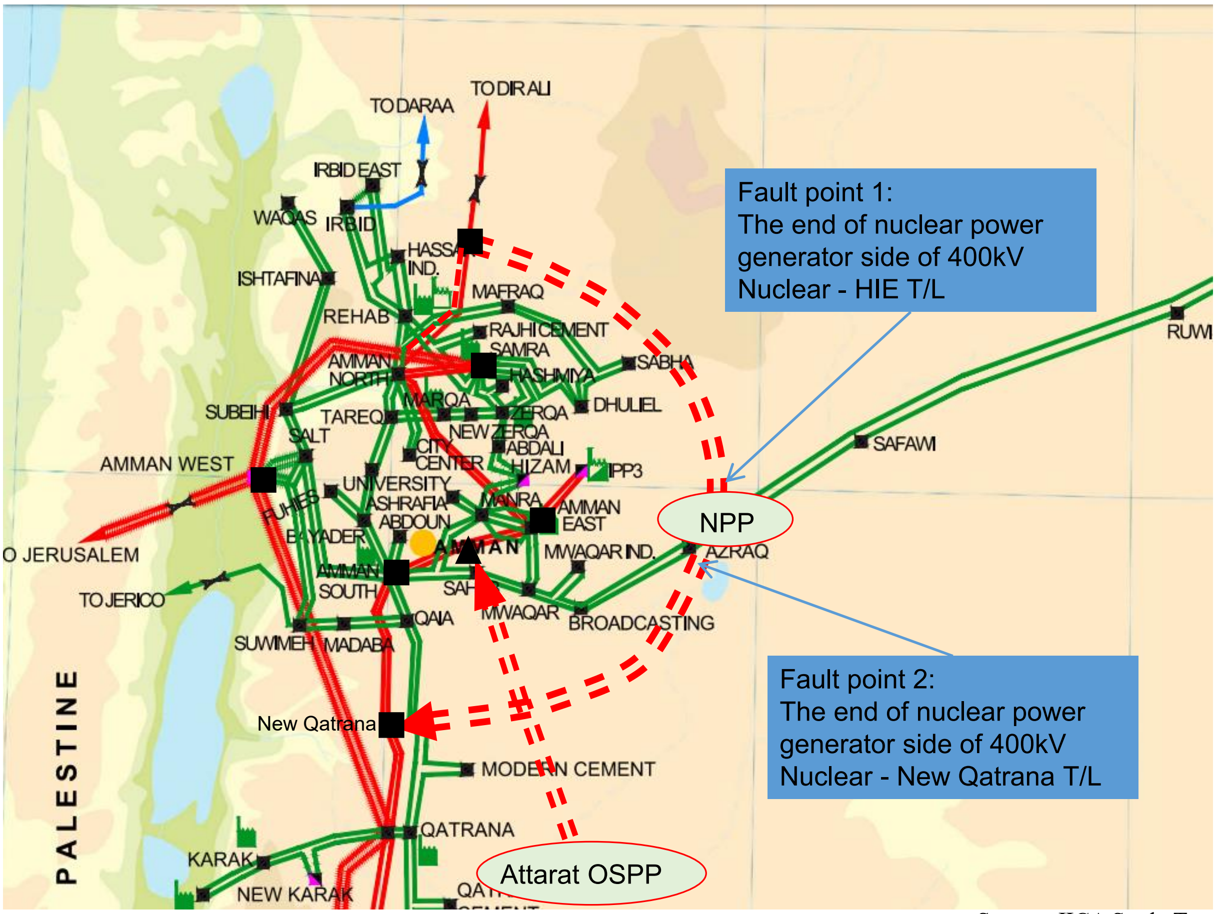
Table 6.3-13 Analysis result for Nuclear power generation plan 4 in 2025

Item	From		To	Study scenarios
				4
132kV transmission line loading in N-1 state	Hizam	-	Manara	-
	Hizam	-	Abdali	196%
	Hizam	-	Samra	141%
	Bayader	-	Amman South	105%
	Marqa	-	Zarqa	141%
	HTPS	-	Zarqa	120%
	HIE	-	Hassan	108%
	Manara	-	Amman South	127%
	Amman South	-	QAIA	-
	QAIA	-	Madaba	101%
400kV transmission line loading in N-1 sate	Samra	-	Amman N	-
400kV substation loading in N-1 state	Amman South			100%
	Amman East			-
	Amman North			102%
	Amman West			-
Single line to ground fault current	Amman South main			28.2kA
	Amman South reserve			16.5kA
	Tareq			26.9kA
	Qatrana main			26.4kA
	Qatrana reserve			14.3kA
	Amman East			31.9kA
	HTPS			39.3kA
Cost [1,000USD]	Construction cost for nuclear			102,599
	Related reinforcement cost			33,456
	Sub total			136,054
	Oilshale T/L cost			82,944
	Total			218,997

Source: JICA Study Team

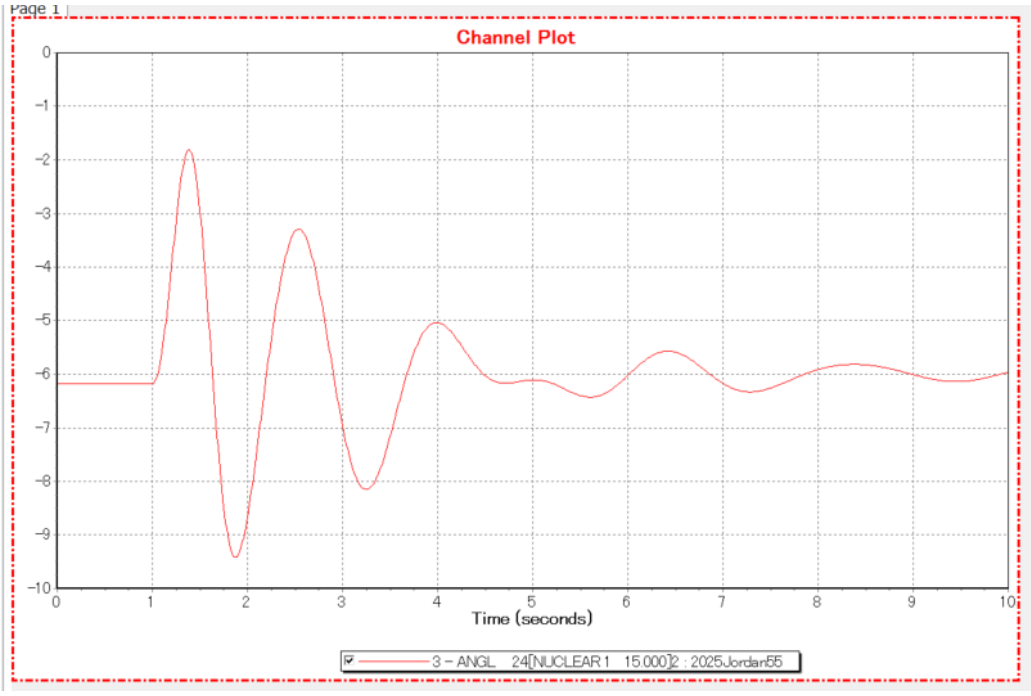
3) Transient stability analysis for nuclear power line tirp in 2025

Transient stability analysys for nuclear power line trip have been studied using PSS/E. The analysis was carried out demand as 3,300MW (55% of summer peak demand) in 2025 power system. Figure 6.3-17 shows fault points. Figure 6.3-18 and Figure 6.3-19 show phase of nuclear generator of 0 to 10 seconds. The fault starts 1.0 second at the end of the nuclear power generator side of nuclear power line. After 0.06 second fault continue, the transmission line are tripped and fault is removed. As the result of analysis, the phase of generator converged in around ten seconds. It was confirmed that transient stability of 2,000MW nuclear power generator was kept to be stable.



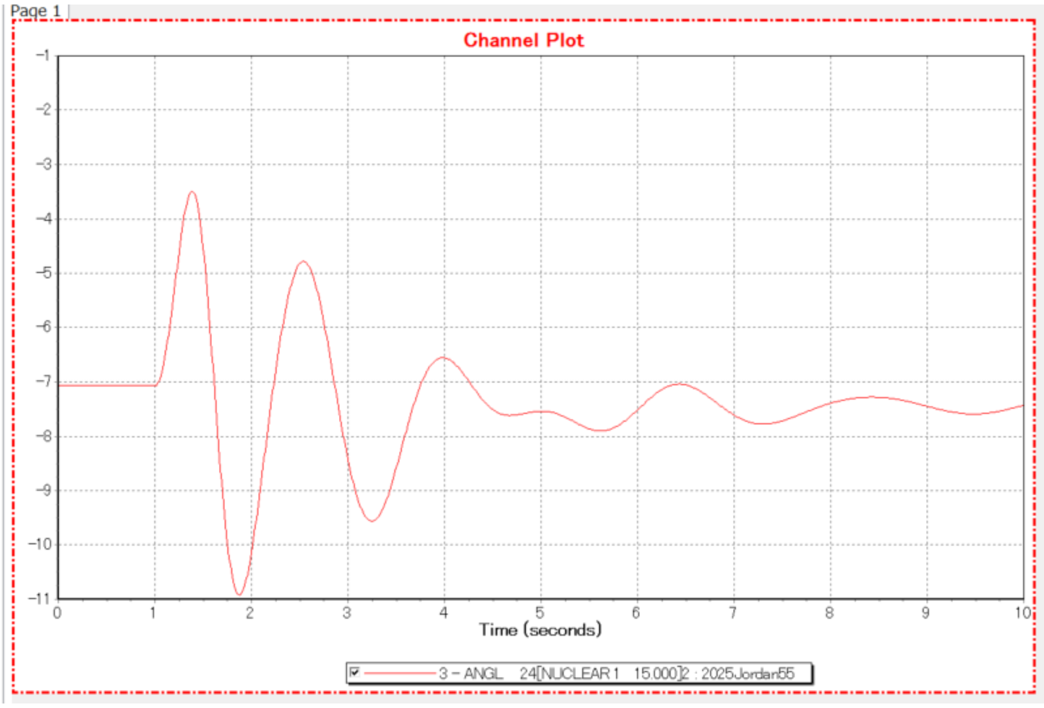
Source: JICA Study Team

Figure 6.3-17 Fault points for analysis of transient stability for Nuclear power generation



Source: JICA Study Team

Figure 6.3-18 Phase of nuclear generator for the nuclear-HIE transmission line fault happened



Source: JICA Study Team

Figure 6.3-19 Phase of nuclear generator for the nuclear-New Qatrana transmission line fault happened

4) N-2 analaysis for nuclear power generation in 2025

The N-2 analysis for nuclear power line consideration of four connection plans for the nuclear power generation in combination with the Attrat oil-shale power plant each connection plans has been studied using PSS/E. The overload transmission line and 400kV transmission line's current and direction were confirmed under the two circuit fault of nuclear transmission lines. Table 6.3-14 - Table 6.3-17 show analysis result for each case of power generation connection plans. As the result of analysis, the current of 400kV transmission lines under the nuclear transmission line's N-2 were less than capacity (1,000*2 MW or 1,247*2 MW) of 400kV transmission lines and the voltage of 400kV substations do not have problem.

Table 6.3-14 Analysis result for nuclear power line's N-2 with nuclear connection plan 1

	Study scenario					
	1-1	1-2	1-3	1-1	1-2	1-3
NPP	HIE-Amman East(Amman East 2cct trip)			HIE-Amman East(HIE 2cct trip)		
OSPP	AMS-AME	QAIA	New Qatrana	AMS-AME	QAIA	New Qatrana
400kV Current Flow	AMS←AME 334MW	AMS←AME 412MW	AMS←AME 390MW	AMS←AME 614MW	AMS←AME 834MW	AMS←AME 814MW
	AME←AMN 470MW	AME←AMN 534MW	AME←AMN 512MW	AME→AMN 984MW	AME→AMN 934MW	AME→AMN 954MW
	AMN←Samra 846MW	AMN←Samra 932MW	AMN←Samra 924MW	AMN→Samra 454MW	AMN→Samra 420MW	AMN→Samra 426MW
	Samra←HIE 914MW	Samra←HIE 960MW	Samra←HIE 952MW	Samra→HIE 426MW	Samra→HIE 392MW	Samra→HIE 400MW
	HIE→AMW 574MW	HIE→AMW 528MW	HIE→AMW 530MW	HIE→AMW 182MW	HIE→AMW 148MW	HIE→AMW 150MW
Over loading T/L	Hizam-Samra (base 109%)	-	-	-	-	-

Note: AMS: Amman-South, AME: Amman-East, AMN: Amman-North, AMW: Amman-West Source: JICA Study Team

Table 6.3-15 Analysis result for nuclear power line's N-2 with nuclear connection plan 2

	Study scenario					
	2-1	2-2	2-3	2-1	2-2	2-3
NPP	HIE-New Qatrana(New Qatrana 2cct trip)			HIE-New Qatrana(HIE 2cct trip)		
OSPP	AMS-AME	QAIA	New Qatrana	AMS-AME	QAIA	New Qatrana
400kV Current Flow	AMS←AME 334MW	AMS←AME 412MW	AMS←AME 390MW	AMS→AME 416MW	AMS→AME 710MW	AMS→AME 732MW
	AME←AMN 470MW	AME←AMN 534MW	AME←AMN 512MW	AME→AMN 662MW	AME→AMN 558MW	AME→AMN 578MW
	AMN←Samra 886MW	AMN←Samra 930MW	AMN←Samra 924MW	AMN→Samra 170MW	AMN→Samra 90MW	AMN→Samra 98MW
	Samra←HIE 914MW	Samra←HIE 960MW	Samra←HIE 952MW	Samra→HIE 144MW	Samra→HIE 64MW	Samra→HIE 70MW
	HIE→AMW 574MW	HIE→AMW 528MW	HIE→AMW 530MW	HIE→AMW 114MW	HIE←AMW 196MW	HIE→AMW 194MW
Over loading T/L	Hizam-Samra (base 101%)	-	-	-	-	-

Note: AMS: Amman-South, AME: Amman-East, AMN: Amman-North, AMW: Amman-West Source: JICA Study Team

Table 6.3-16 Analysis result for nuclear power line's N-2 with nuclear connection plan 3

	Study scenario					
	3-1	3-2	3-3	3-1	3-2	3-3
NPP	HIE-Samra(Samra 2cct trip)			HIE-Samra(HIE 2cct trip)		
OSPP	AMS-AME	QAIA	New Qatrana	AMS-AME	QAIA	New Qatrana
400kV Current Flow	AMS←AME 334MW	AMS←AME 412MW	AMS←AME 390MW	AMS←AME 430MW	AMS←AME 556MW	AMS←AME 536MW
	AME←AMN 470MW	AME←AMN 534MW	AME←AMN 512MW	AME←AMN 666MW	AME←AMN 726MW	AME←AMN 706MW
	AMN←Samra 886MW	AMN←Samra 930MW	AMN←Samra 924MW	AMN←Samra 1184MW	AMN←Samra 1226MW	AMN←Samra 1218MW
	Samra←HIE 914MW	Samra←HIE 960MW	Samra←AMW 952MW	Samra→AMW 766MW	Samra→AMW 724MW	Samra→AMW 730MW
	HIE→AMW 574MW	HIE→AMW 528MW	HIE→AMW 530MW	HIE→AMW 448MW	HIE→AMW 406MW	HIE→AMW 410MW
Over loading T/L	Hizam-Samra (base 102%)	-	-	-	-	-

Note: AMS: Amman-South, AME: Amman-East, AMN: Amman-North, AMW: Amman-West Source: JICA Study Team

Table 6.3-17 Analysis result for nuclear power line's N-2 with nuclear connection plan 4

	Study scenario	
	4	
NPP	HIE - New QAIA (HIE 2cct trip)	HIE - New QAIA (New QAIA 2cct trip)
OSPP	New QAIA	New QAIA
400kV Current Flow	Amman South → Amman East 782MW	Amman South ← Amman East 415MW
	Amman East → Amman North 627MW	Amman East ← Amman North 540MW
	AMN→Samra 153MW	AMN←Samra 941MW
	Samra→HIE 126MW	Samra←HIE 968MW
	HIE← Amman West 133MW	HIE→ Amman West 510MW
	AMS ← New QAIA 1558MW	AMS ← New QAIA 311MW
Over loading T/L	Bayader- Amman South (Base 108%)	Bayader- Amman South (Base 110%) Hizam-Samra (Base 109%)

Source: JICA Study Team

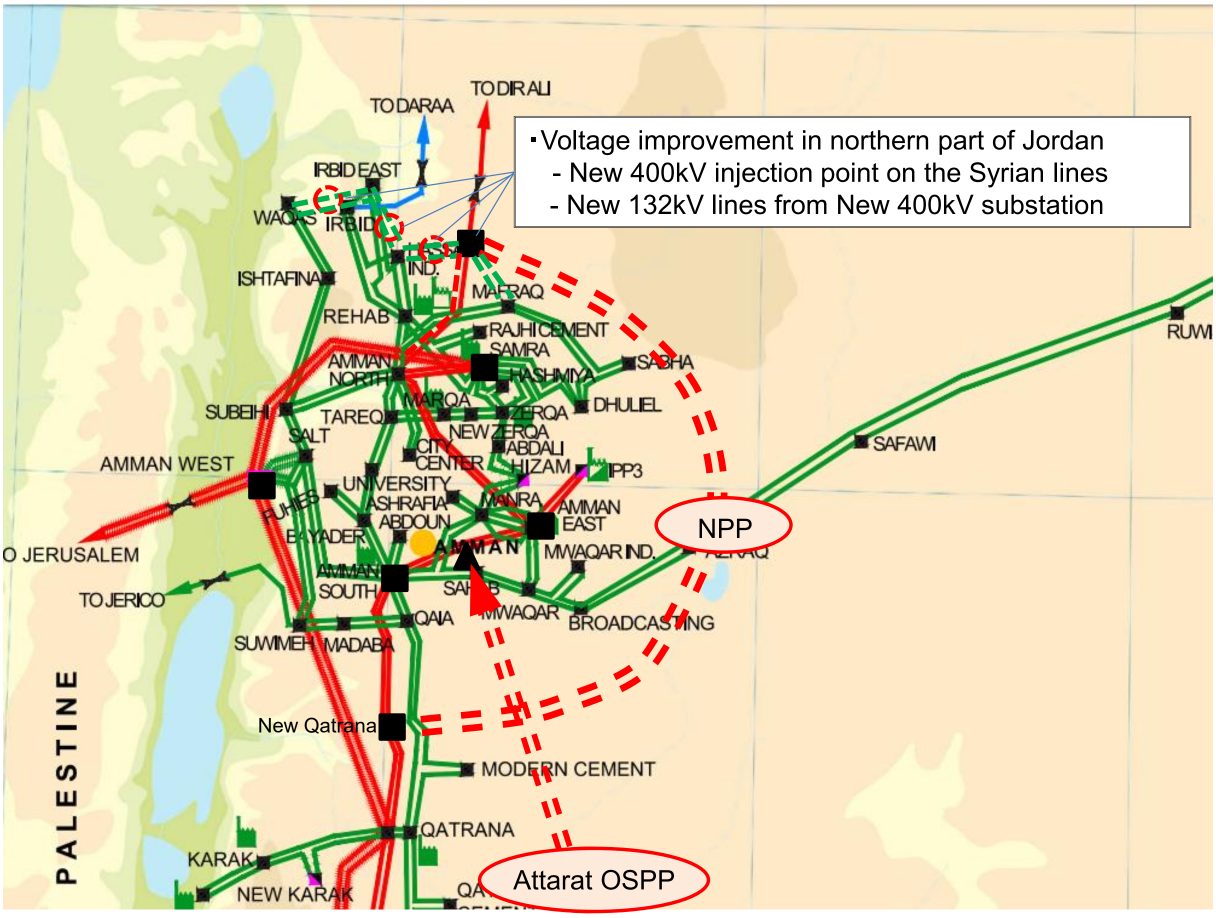
6.3.4 Power system planning for the 2025, 2030, 2034

1) Meaasures for the 2025 power system

(i) Power system for the nuclear on schedule

Figure 6.3-20 shows measures for the nuclear on schedule power system in 2025. The measures are proposed as follows.

- ✓ New CCGTs are supposed to be located at Rehab and new 400kV injection points in the North area.
- ✓ Voltage improvement projects in the northern part of Jordan. The projects are new 132kV transmission line from HIE to Mafraq, Hassan industrial, Irbid East, Irbid and Waqas.
- ✓ 400kV loop system to connect with the nuclear power generation.
- ✓ Replacement to superheated conductors for reliability improvement in 132kV power system such as Hizam-Abdali, Hizam-Samra, Bayader - Amman South are proposed.



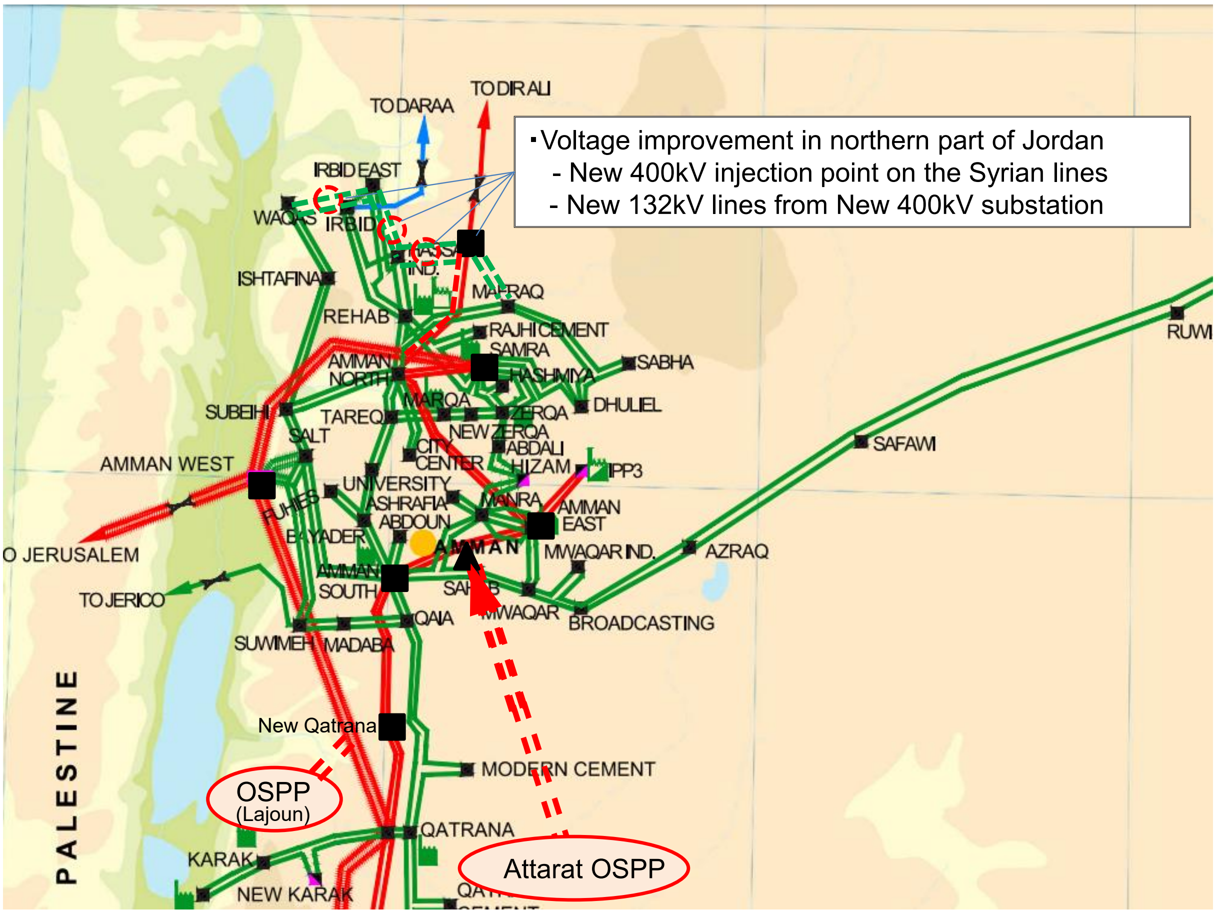
Source: JICA Study Team

Figure 6.3-20 Power system for nuclear on schedule in 2025

(ii) Power system for the nuclear behind schedule

Figure 6.3-21 shows measures for the nuclear behind schedule power system in 2025. The measures are proposed as follows.

- ✓ New CCGTs are supposed to be located at Rehab, new 400kV injection points and Hassan industrial in the North area.
- ✓ Voltage improvement projects in the northern part of Jordan. The project are new 132kV transmission lien form HIE to Mafraq, Hassan industrial, Irbid East, Irbid and Waqas.
- ✓ A new coal thermal in Aqaba.
- ✓ A new oil-shale power plant in Lajoun.



Source: JICA Study Team

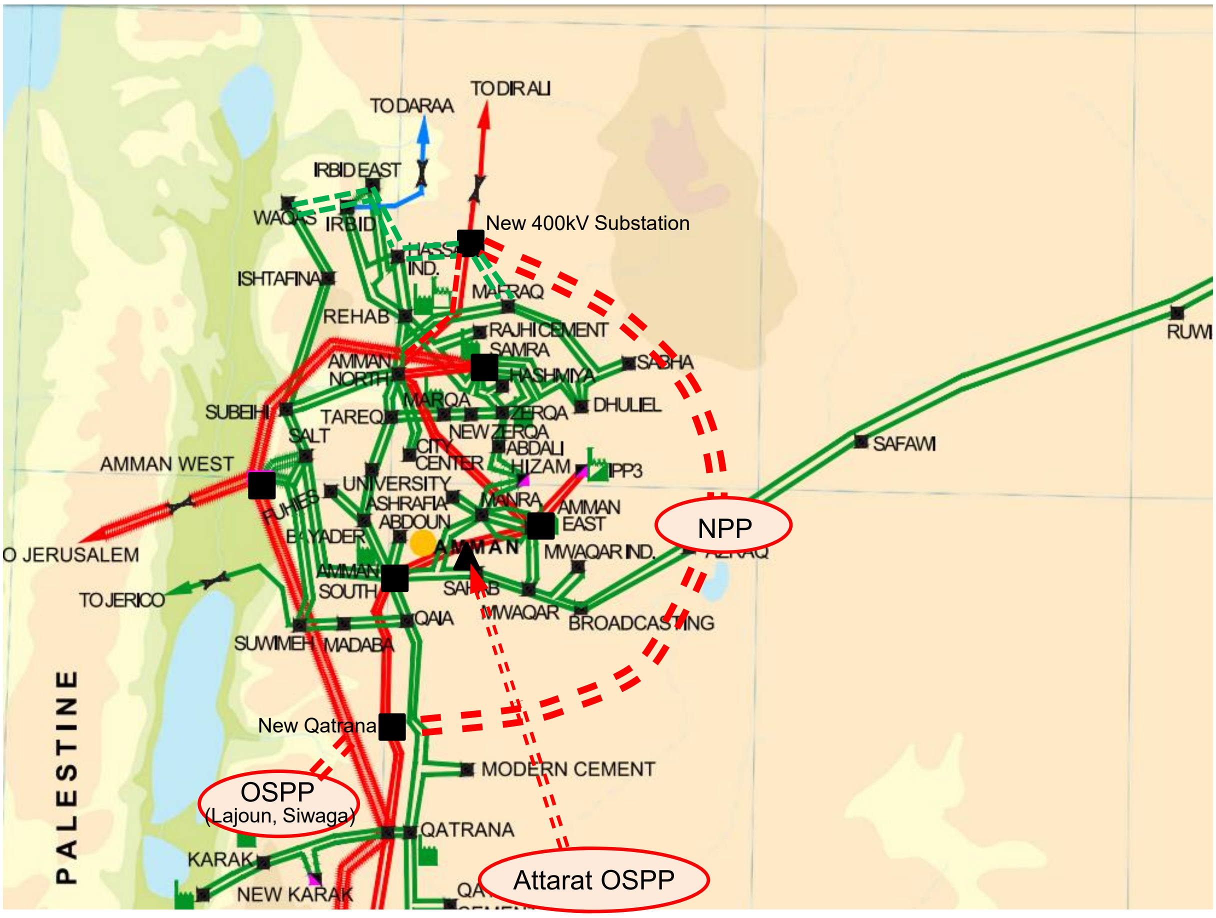
Figure 6.3-21 Power system for nuclear behind schedule in 2025

2) Meaasures for the 2030 power system

(i) Power system for the nuclear on schedule

Figure 6.3-22 shows measures for the nuclear on schedule power system in 2030. The measures are proposed as follows.

- ✓ New CCGTs are supposed to be located at Rehab, new 400kV injection points and Hassan industrial in the North area.
- ✓ A new coal thermal in Aqaba.
- ✓ A new oil-shale power plant in Lajoun.
- ✓ An installation of 400/132kV transformers in the Amman East, Amman West, Amman North and Amman South.



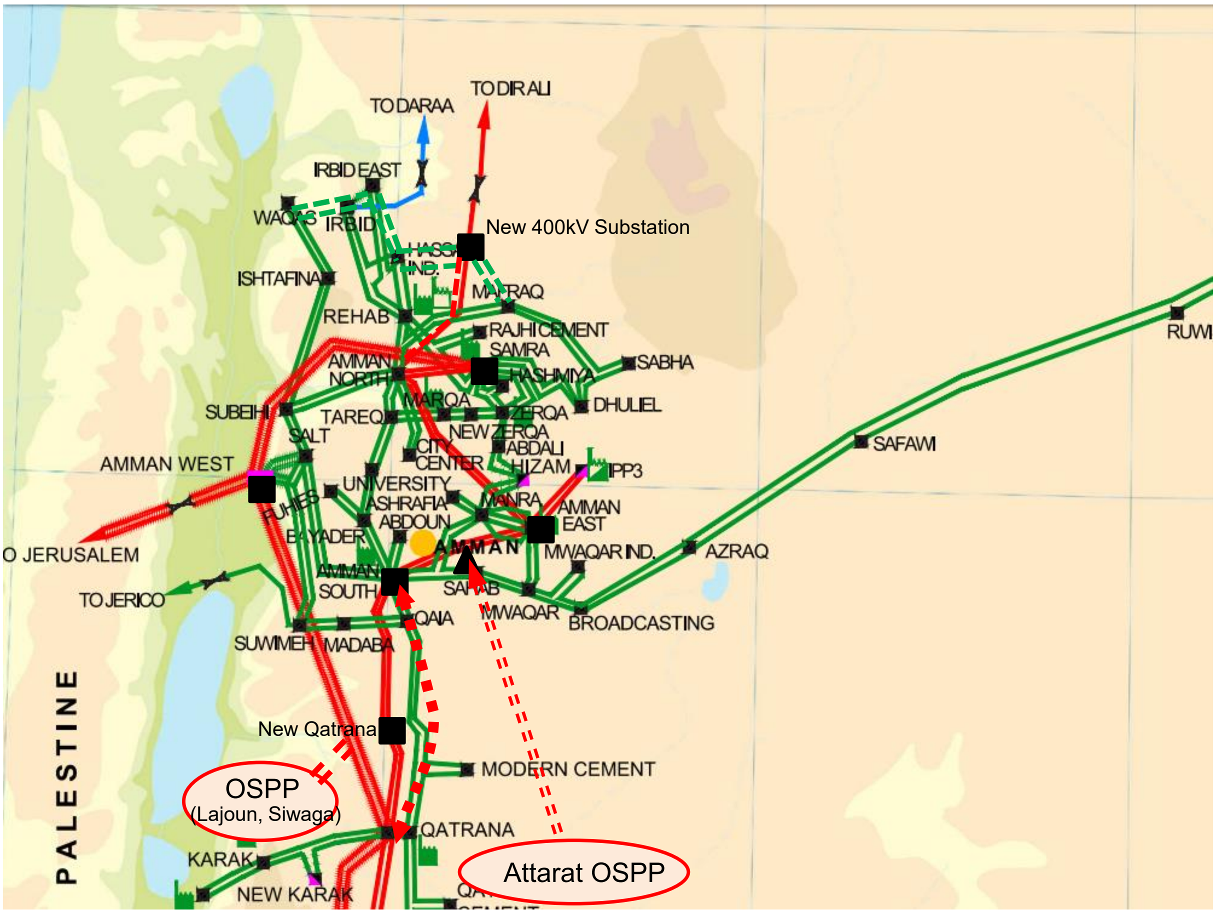
Source: JICA Study Team

Figure 6.3-22 Power system for nuclear on schedule in 2030

(ii) Power system for the nuclear behind schedule

Figure 6.3-23 shows measures for the nuclear behind schedule power system in 2030. The measures are proposed as follows.

- ✓ To supply much power from the oil-shale power plant in Lajoun and Siwaga.
- ✓ 400kV transmission lines from Amman South to Qatrana should be reinforced
- ✓ New CCGTs are supposed to be located at Amman West, Karak, Sabha and ATPS.



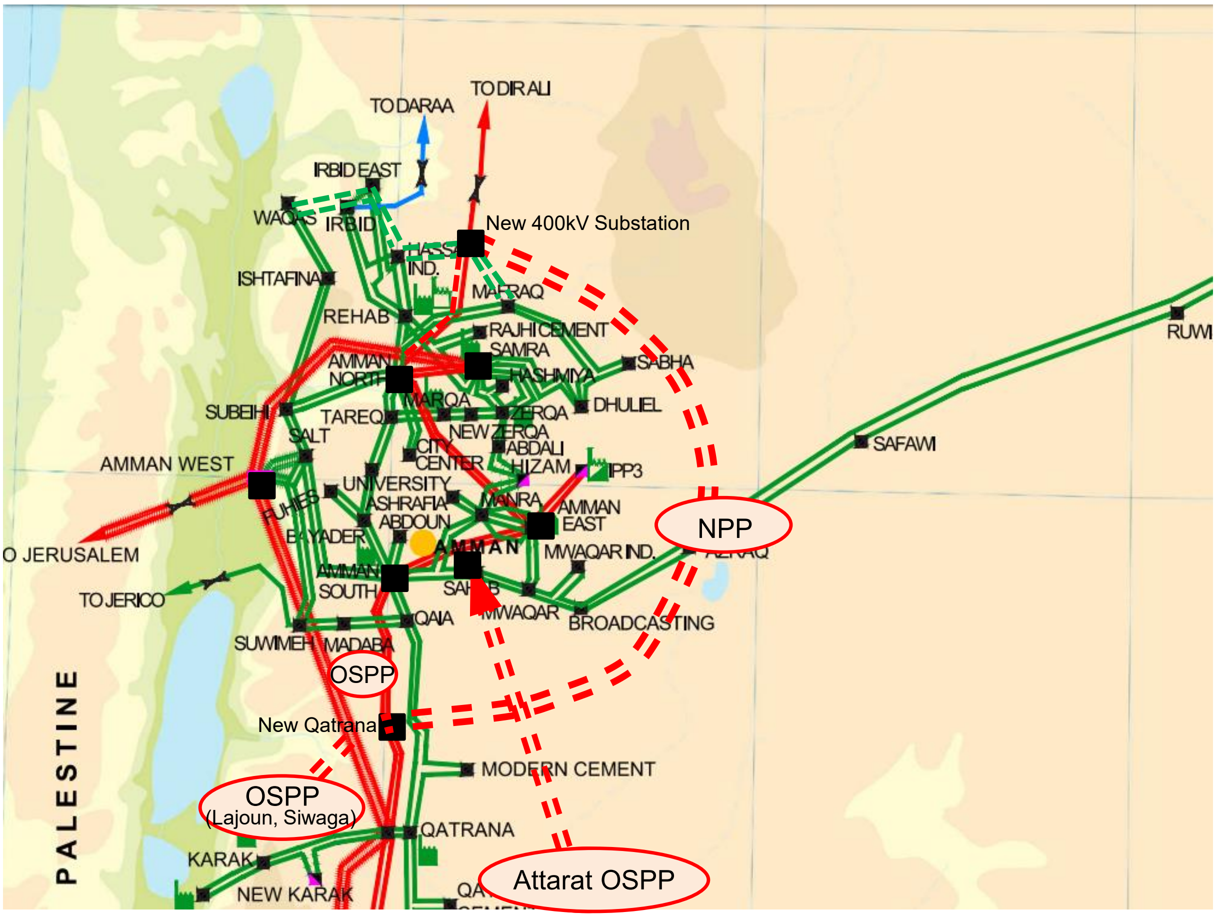
Source: JICA Study Team

Figure 6.3-23 Power system for nuclear behind schedule in 2030

3) Meaasures for the 2034 power system

Figure 6.3-24 shows measures for the power system in 2034. The measures are proposed as follows.

- ✓ New CCGTs are supposed to be located at Amman West, Karak, Sabha and ATPS.
- ✓ New 400kV injection point between Amman South and Amman East
- ✓ Installation of 400/132kV transformers in Aqaba, Qatrana and new 400kV substation.



Source: JICA Study Team

Figure 6.3-24 Power system in 2034

4) Capital investment cost for power system up to 2034

Table 6.3-18 shows BSP plans and transmission plans capital investment cost. The total capital investment cost for the power system is estimated at around 1,000 million US dollars.

Table 6.3-18 Capital investment cost for the power system

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">BSP plans</th><th colspan="2">Transmission plans</th></tr>
<tr><th>Nuclear
on schedule</th><th>Nuclear
behind schedule</th></tr>
<tr><td>2016 –
2020</td><td>53
(including NEPCO committed project cost: 45MlnUS$)</td><td colspan="2">436
(including NEPCO committed project cost: 322MlnUS$)</td></tr>
<tr><td>2021 –
2025</td><td>70</td><td>231</td><td>117</td></tr>
<tr><td>2026 –
2034</td><td>136</td><td>94</td><td>226</td></tr>
<tr><td>Total</td><td>259</td><td>761</td><td>779</td></tr>
</table>

Source: JICA Study Team

5) Impact of renewable energy introduction for the power system in 2034

This chapter explained the impact of renewable energy introduction for the power system in 2034 under the condition of spring peak demand that is 60% of the peak demand in summer season. Table 6.3-19 shows the analysis result of current under N-0 state, N-1 state and reinforcement cost consideration of increase of renewable energy introduced up to 3,120MW. As a result of the analysis, 400kV New Ma'an substation and 400kV Qatrana-New Qatrana transmission line should be reinforced for securing the N-1 condition in case that over 3,000MW of renewable energy, mainly developed in the southern area of Jordan, is introduced.

Table 6.3-19 Analysis result of impact of renewable energy introducution

Load	Peak demand	60% peak demand			
Renewable	1,248MW	1,248MW	1,872MW	2,496MW	3,120MW
Current flow(N-0)					
400kV ATP-New Ma'an	731MW (24%)	881MW (26%)	938MW (28%)	990MW (30%)	1,046MW (34%)
400kV New Ma'an-Qatrana	717MW (25%)	1,018MW (32%)	1,257MW (39%)	1,488MW (47%)	1,720MW (57%)
400kV Qatrana-NewQatrana	455MW (26%)	457MW (25%)	597MW (33%)	732MW (42%)	883MW (54%)
400kV Qatrana-Amman West	180MW (13%)	247MW (10%)	363MW (14%)	475MW (19%)	573MW (23%)
400kV New Qatrana- Amman South	1,335MW (36%)	1,250MW (32%)	1,339MW (35%)	1,404MW (37%)	1,460MW (39%)
132kV QAIA-Amman South	149MW (42%)	72MW (31%)	50MW (24%)	31MW (15%)	11MW (6%)
132kV QAIA-Madba	196MW (62%)	137MW (35%)	147MW (37%)	234MW (40%)	164MW (42%)
Reinforcement T/L, S/S (N-1 state)	400kV Qat S/S 400kV AMN S/S 400kV AMW S/S 400kV ATP S/S 400kV HIE S/S			400kV New Ma'an S/S Reinforcement cost 4,230kUSD	400KV Qat-New Qat T/L 132kV Qat-Qat Cem, EL Hasa-Qat Cem, Qat-EL Hasa Reinforcement cost 48,743kUSD

Source: JICA Study Team

6.3.5 Renewable Energy

In the study of generation development planning, installation of battery storage system would be studied to keep a fixed operating reserve margin for each year's generation configuration against huge renewable energy installation. And system planning would be studied future grid configuration in line with huge output provision from renewable energy.

In this session, ancillary services with battery storage system utilization should be considered on operations aspect for system planning.

(1) Ancillary services

Ancillary service determined by NEPCO is the one defined in an agreement, other than the production of energy and/or provision of capacity, which is used to operate a stable and secure power system including automatic generation control, reactive power, operating reserve, frequency control, voltage control and black start capability.

According to NEPCO transmission grid code, condition of ancillary services are determined as follows,

Generating units that have contracted to the TSO to provide ancillary services must be capable of contributing such services as follows:

(a) Spinning reserve by supplying active power according to its operational capabilities as set out in the connection agreement[3]. Spinning reserve requirements shall be determined by the TSO on a regular basis.

(b) The capability of contributing to frequency control or transfer control (AGC and LFC) shall be as set out in the connection agreement. The required participation shall be determined by the TSO on a regular basis.

(c) Each generating unit must be capable of supporting voltage regulation at the connection point as detailed in its connection agreement.

(2) Suggestion for ancillary services against huge renewable energy installation in Jordan

In Jordan, power producer(s) and NEPCO as TSO, and as transmission system network provider contract the connection agreement, which involves the requirement of ancillary services to meet the characteristics of the generation unit(s). And the generator(s) are driven to provide the power and designated services based on the command from TSO after connecting the grid[4].

So far, several renewable energy power plants exist and even commitments and contracts between renewable energy power producer entities and NEPCO. In this situation, amendment of the contracts integrating with battery storages is not realistic. Therefore it is feasible to introduce battery storage system simple substance as ancillary servicing generator(s).

NEPCO, single buyer in Jordan, will conduct the charge-discharge plan based on the periodical generation plan, such as weekly, daily, and hourly (spot) from renewable energy power producers. This features and procedures will be desirable for power flow reduction in a critical transmission and/or constant power flow in a reasonable percentage of its capacity. Further, it will be useful to be enable to peak-cut operations.

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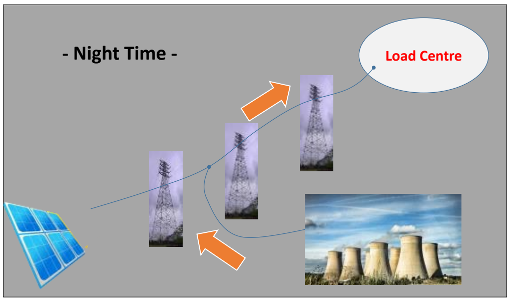
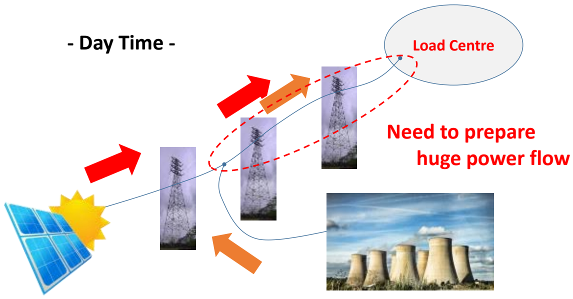
[3] An agreement between a user and NEPCO as TNSP and as TSO, which sets the conditions for the connection and operation coordination of that user to the transmission network at a connection point. (NEPCO Transmission Code, 2010)

[4] NEPCO Transmission Grid Code, 2010

＜Current Planning＞





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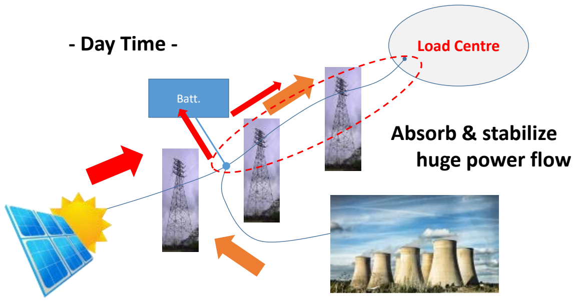

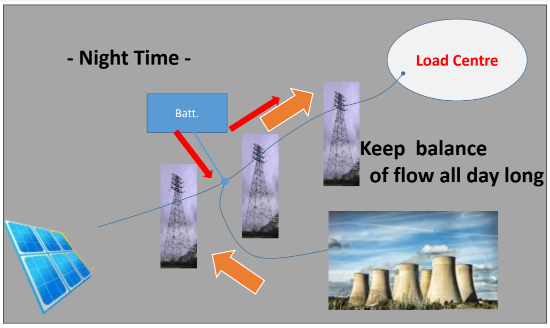

However, following issues are still uncertain at the time for conducting precise study.

- Renewable energy output hit rate
- Other generation plants situation (planning and operating) surrounding renewable energy
- Peak demand hit rate

In order to determine the condition of battery storage (power plant), such as capacity, location etc., aforementioned constraints need to be well studied and would be studied regarding efficiency in short, medium term planning.