Japan International Cooperation Agency (JICA)

Ministry of Electricity and Water
Sultanate of Oman

The Study on Demand Supply Management for Power Sector in Sultanate of Oman

Final Report

Summary

November 1998

PROACT International, Inc.
Shikoku Research Institute, Inc.

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TABLE OF CONTENTS

1. Fundamental Problems in Electricity Supply

Over the past ten years, the demand for electricity has been growing steadily in Oman. Because of the hot and humid weather, the demand for air conditioning is extremely large during the summer season. The two main systems, Muscat system and Wadi Jizzi system, however, do not have enough supply capacity, which results in frequent load shedding. It is, therefore, an urgent issue to develop generation plants quickly to secure necessary capacity and spinning reserve. At the same time, Demand Side Management(DSM) must be seriously considered to suppress the demand growth by peak shifting, peak shaving, or use of other energy sources.

Gas turbine generators are mostly used in the Muscat and Wadi Jizzi systems. According to the characteristics of gas turbine, the output of generation plant goes down when the ambient temperature is high. This is a big disadvantage for the power supply in Oman. Another problem is that the way of operating generation plant is not efficient. To secure necessary spinning reserve, many generators are operated at partial load, which leads to lower fuel efficiency.

In addition to the supply shortage problem, the financial structure of power supply has been another serious problem. The revenue shortfall is significant. The revenue from electricity sales, 87.7 million RO, covers only 57.5% of the total cost, 152.65 million RO. As capital intensive power supply business requires huge amount of continuos investment, to improve financial position is extremely important to provide reliable power supply in the long run. The bottom line of electricity supply should be improved. Necessary measures for both cost reduction and revenue increase must be undertaken in a timely manner.

2. Demand Forecast

Before developing a master plan for the power sector over the next ten years, a precise demand forecast is needed. Based on the actual data of 1998 and methodologies in the Fichtner's master plan, a revised demand forecast has been prepared as follows. (Table S-1) This is the baseline for future planning of the power sector.

Table S-1 Forecasts of Power Demand (MW)

Year	Fichtner Forecast		After Modification			
	Muscat	Wadi Jizzi	Muscat	Growth. Rate	Wadi Jizzi	Growth. Rate
1997	1129	295	1080	-	293	-
1998	1185	317	1210	12.0%	310	5.8%
1999	1242	335	1268	4.8%	328	5.7%
2000	1393	358	1423	12.2%	350	6.9%
2001	1482	375	1514	6.4%	367	4.7%
2002	1571	390	1605	6.0%	381	4.0%
2003	1658	404	1693	5.5%	395	3.6%
2004	1720	418	1756	3.7%	409	3.5%
2005	1782	432	1820	3.6%	422	3.3%
2006	1842	447	1880	3.4%	437	3.5%
2007	1901	462	1940	3.2%	452	3.4%
2008	1958	476	2000	3.0%	465	3.0%
2009	2016	491	2060	3.0%	480	3.2%
2010	2075	507	2120	2.9%	496	3.3%

The generation expansion plan, like other electric power facility plans, is based on the (N-1) criterion. This approach can be defined as follows:

a. To prevent a supply shortage, in case of a large drop in the power source output, each power system is developed to have a capacity equivalent to the maximum power demand plus the capacity of the largest generator.

b. The capacity of each developed unit is limited from 15% to 20% of the total capacity of the power system.

In recent years, supply shortages due to delays in power source development has become more and more serious. Operation is quite tight and troubles on small-capacity units force the system to do load shedding very often. Supply power needs to be secured as quickly as possible in preparation for the next summer. In order to increase the power output within a short period, water injection and inlet air cooling to existing gas turbines are analyzed.

3. Gas Turbine Improvement

(1) Water Injection

Injecting water into the head end of the combustor for NOx abatement increases mass flow, and therefore, output. Water or steam injection for power augmentation has been an available option on GE gas turbines over 30 years and this is a well proven technique.

As water injection is very effective for power augmentation, it is recommended to apply water injection to all gas turbines with the exception of GT12 and GT13 of Ghubrah power station, to which the heat recovery boiler for desalination plant is connected, and GT1 and GT2 of Wadi Jizzi power station, which are owned by another company. Namely, water injection shall be applied to the following units. Extra supply capacity, as much as 152MW, can be secured for the 1999 summer peak by completing modification work in time.

- Ghubrah power station : GT1-GT11; Frame 5 and Frame 6
- Rusail power station : GT1-GT6; Frame 9
- Wadi Jizzi power station : GT3-GT11; Frame 5 and Frame 6

Table S-2 Output increase and water tank capacity

Object Units		Output Increase (MW)	Tank Capacity (t)
Ghubrah PS	GT 1～11	29.1	800
Rusail PS	GT 1～6	93.8	2,200
Wadi Jizzi PS	GT 3～11	29.1	800

The total output increase of three power stations, 152MW, under water injection operation is almost equivalent to the output increase when one Frame 6 unit, one Frame 9 unit and one Frame 6 unit are additionally installed to the Ghubrah, Rusail and Wadi Jizzi power stations respectively. Therefore, a financial study has been conducted by comparing costs and benefits of water injection operation with those of operation by additional three gas turbines.

①Investment

A comparison of investment amount in both cases is made in Table S-3.

Table S-3 Comparison of Investment

Unit : RO 1000

Power Station	Total Investment Amount		
	GT Addition	Water Injection	Difference
Ghubrah	6,660	2,630	- 4,030
Rusail	13,850	2,420	- 11,430
Wadi Jizzi	6,660	2,280	- 4,380
Total	27,170	7,330	- 19,840

In water injection operation, power can be augmented, however, additional operation costs such as more fuel cost due to lower gas turbine efficiency and injection water cost are necessary.

②Overall Evaluation

The net present value (NPV) of the associated cash flow over 20 year period is calculated (Table S-4). In conclusion, it is clear that the water injection operation is far more profitable than adding new gas turbines by NPV of 15 million RO. It is, therefore, highly recommended to apply water injection to existing gas turbines as a means of power augmentation in the summer peak load time. Negotiations with gas turbine manufacturers should be started as soon as possible.

Table S-4 Total Evaluation of Water Injection vs New Gas Turbines

Unit : RO 1000

Power Station.	Cost difference		NPV of
	Investment	Generation Cost	Water Injection
Ghubrah	- 4,030	+ 50	+ 3,078
Rusail	- 11,430	+ 129	+ 8,863
Wadi Jizzi	- 4,380	+ 42	+ 3,466
Total	- 19,840	+ 221	+15,407

(2) Inlet Air Cooling

Gas turbines increase output when ambient temperature goes down. Inlet air cooling is a technology to boost gas turbine output by taking advantage of this phenomenon. Technically, it is possible to apply inlet air cooling to any existing gas turbine unit; however, it is not economical to apply to small gas turbines such as Frame 5 or Frame 6. Therefore, the study has been focused on the application of inlet air cooling to six Frame 9 units in the Rusail power station. The total output increase of the Rusail power station with an inlet air cooling operation is almost equivalent to the output increase when one Frame 9 unit is additionally installed in the power station. Therefore, a financial study has been conducted by comparing the cash flow of inlet air cooling operation with that of operation by additional one Frame 9 gas turbine.

By cooling down the ambient temperature to 20°C, one unit of Frame 9 will increase its output from 102.1MW to 119.1MW (Ambient temp. : 40°C). The total output of the Rusail power station when inlet air cooling is applied will be approximately 100MW, which is almost equivalent to one Frame 9.

①Investment

Comparison of investment amount is shown in Table S-5. Investment in an inlet air cooling system is approximately 70% of the cost of additional installation of a new gas turbine.

Table S-5 Comparison of Investment

Unit : RO 1000

Power Station	Total Investment Amount		
	GT Addition	Inlet Cooling	Difference
Rusail	13,850	10,160	- 3,690

②Overall Evaluation

The NPV of the associated cash flow over 20 year period is calculated. In conclusion, it is clear that an inlet air cooling operation is also profitable than adding a new Frame 9 gas turbine. The NPV of inlet air cooling is positive; 2.7 million RO.(Table S-6) But, if both a water injection and an air cooling operation are applied at the same time, the output of gas turbine will exceed the capability of electrical equipment such as generator, main transformer etc. Therefore, the water injection operation, which has larger NPV than the inlet air cooling, should be applied preferentially.

Table S-6 Overall Evaluation of Inlet Air Cooling vs Adding New Gas Turbine

Unit : RO 1000

Rusail Power Station.	Cost difference		NPV of Inlet Air Cooling
	Investment	Generation Cost	
	- 3,690	+ 57	2,710

Gas Turbine Output Improvement by Water Injection

Increasing Output ; 152 MW
Investment Cost ; 7.33 mil RO
<u>NPV of water injection ; 15.4 mil RO (1999-2018)</u>

4. System Interconnection

The Wadi Jizzi system is a small capacity system, but the power demand growth rate is relatively high. To secure the specified level of reliability, continuous investment in new generators must be made. However, the following restraints must be also considered.

- System size prohibits the development of large capacity unit (95 MW class).
- When a relatively large capacity unit (60 MW class) is developed, operation requires a spinning reserve equivalent to the largest generator.

These conditions force the capacity of units to be small (30 MW class). Frequent investments in small units are needed, but lagged behind. This has caused a supply capacity shortage in recent years. If the Wadi Jizzi system is interconnected with the Muscat system, substantial benefits are expected as follows.

① Benefits of Interconnection

a. Diversity

The diversity of maximum demand between the Muscat system and the Wadi Jizzi system is about 4%. Accordingly, the system interconnection should allow for a power source reduction equal to 2% of the total capacity.

b. Reduction of Spinning Reserve

With this interconnection, the Wadi Jizzi system can share its spinning reserve with the Muscat system and reduce its present spinning reserve (maximum capacity: 30 MW) to zero.

c. Operation of the Wadi Jizzi Power Station at higher efficiency

Currently the average operating load factor of Wadi Jizzi PS is about 53 %. If the Wadi Jizzi system is interconnected with the Muscat system, the gas turbines can be operated at a higher load factor corresponding to the elimination of this spinning reserve with a significant fuel expense reduction of about 13.9 %.

Calculating the generation expansion capacity of the interconnected and isolated cases, the interconnected case proved that, from 2001 to 2018, new generation capacity can be reduced by 176MW. This is because the Wadi Jizzi system no longer needs its own spinning reserve and the effect of diversity. This will significantly lower investment costs. Furthermore, a significant amount of fuel cost reduction is possible due to higher load factor of Wadi Jizzi power station.

Investment cost of interconnection	7,530,000 RO
Overall reduction in investment costs (present value)	15,285,000 RO
Reduction of fuel expenses (2001 to 2018)	15,537,000 RO
Net Present Value of Interconnection	30,822,000 RO

②Voltage Drop Problem

Even now, the voltage drops at Saham, Dank, and Ibri SS in the Wadi Jizzi system, and at Khabura and Musanna SS in the Muscat system, are serious problems. Occasionally, the load has dropped out on long, rural transmission lines during the summer peak. Examinations concluded that this problem was caused by a shortage of reactive power, not by a collapse in voltage stability or by reaching transmission limits. Preventative measures call for the immediate installation of static capacitors (SCs) to improve the power factor and increase the voltage of the 132kV and 33kV transmission system..

These problems must be solved urgently by installing static capacitors. This is a separate issue from the interconnection.

Table S-7 Problems and Measures for 132KV System

Name	Problems	Measures
Barka SS 33kV Bus	Low Voltage	Install 10MVA SC
Musanna SS 33kV Bus	Low Voltage	Install 40MVA SC

Table S-8 Problems and Measures for 33KV System of Musanna SS

Name	Problems	Measures	Remarks
Khaborah fdr-2	Limit of transmission	Introduction of 132kV transmission line	Already planned (132KV transmission line)
Rustaq-2 SS 11kV Bus	Low Voltage	Install 5MVA SC	
Sana Bani Gafar SS 11kV Bus	Low Voltage	Install 3MVA SC	
Suweiq-2 SS 11kV Bus	Low Voltage	Install 5MVA SC	
Marble Factory SS 11kV Bus	Low Voltage	Install 3MVA SC	
Wadi Jawahir SS 11kV Bus	Low Voltage	Install 3MVA SC	

<u>Total Investment for voltage problems ; 0.6 mil RO</u>

③Stability of Interconnection

A case of operating the Muscat system and the Wadi Jizzi system independently until the year 2000 and interconnecting both systems in 2001 was examined in terms of system voltage and system stability.

a. System voltage

Section examined : 2001 Year

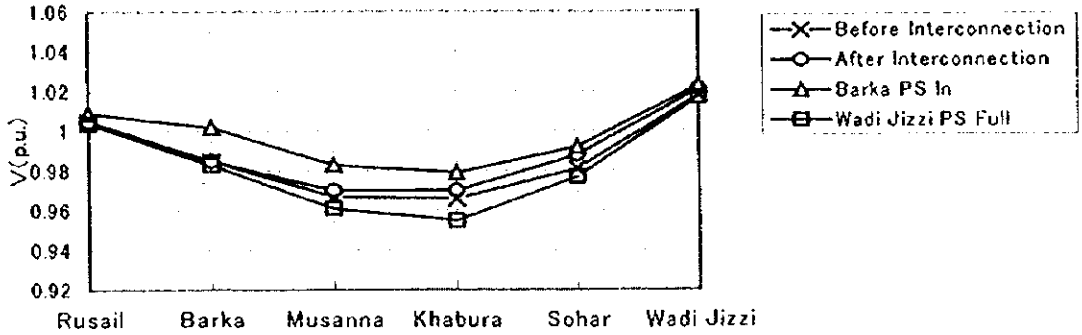


Figure S-1 132kV Bus Voltage (2001)

The above diagram shows as follows:

- When the voltage is maintained in each system, the interconnection will not generate any voltage problem.
- When the Barka power station is newly built and connected in parallel with the system at the Barka SS, the voltage of the interconnection line will rise, and the system stability will be improved.
- When the Wadi Jizzi PS is operated fully, the transmitted power to the Muscat system will increase and the voltage of the interconnection line will drop a little. However, the voltage will be still in the target voltage range and will not pose any problem.
- In 2001 and beyond, with the increase in demand, the voltage will drop gradually. However, new establishment of Barka PS in the aspect of supply capability, and addition of an SC in the Khabura SS in the aspect of voltage, will help the system to maintain the voltage.

On the basis of these findings, it is possible to maintain the voltage of the interconnecting line after the completion of interconnection.

b. Stability

Section examined : 2001 Year

- Muscat system and Wadi Jizzi system are simulated in contraction.

Characteristics and voltage regulator of generators are on standard model in Japan. Transmission lines, transformers, loads and capacitors situated between the Rusail PS and the Wadi Jizzi PS are simulated in detail.

Fault condition :

- Single phase ground fault.

Fault point is the most severe fault point between Rusail PS and Wadi Jizzi PS (Figure S-2).

Sequence of breaking an electric circuit is shown in Figure S-3.

Results of examination :

The disturbance waveforms calculated by simulation are shown in Figure S-4 and Figure S-5.

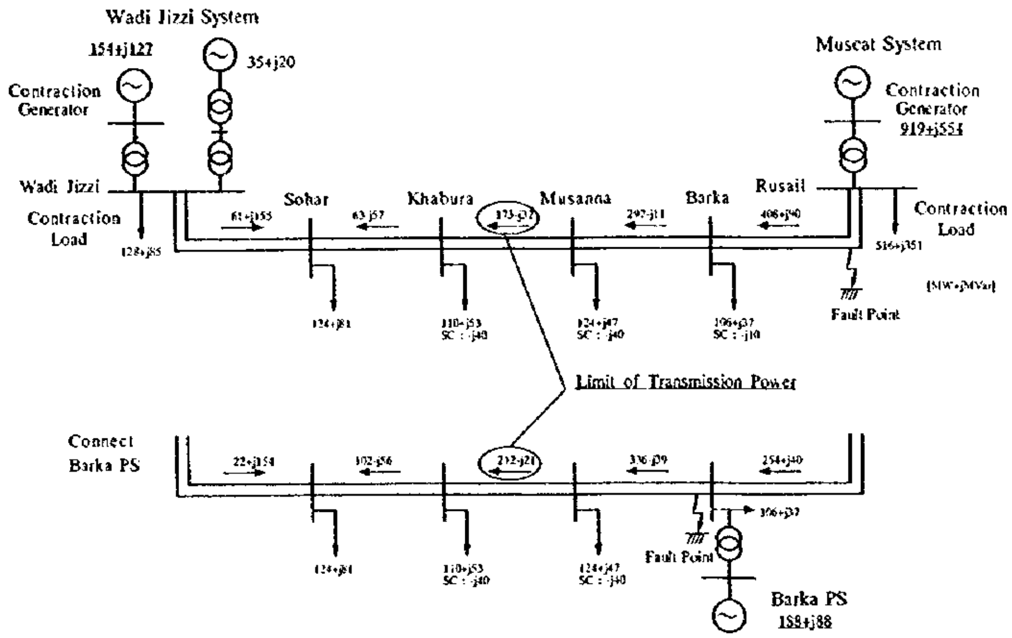


Figure S-2 System model for the stability analysis

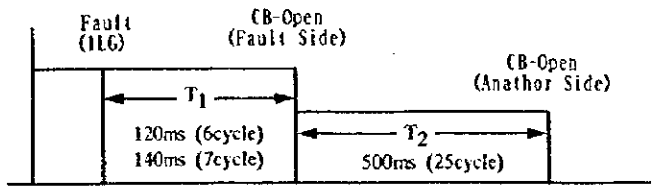
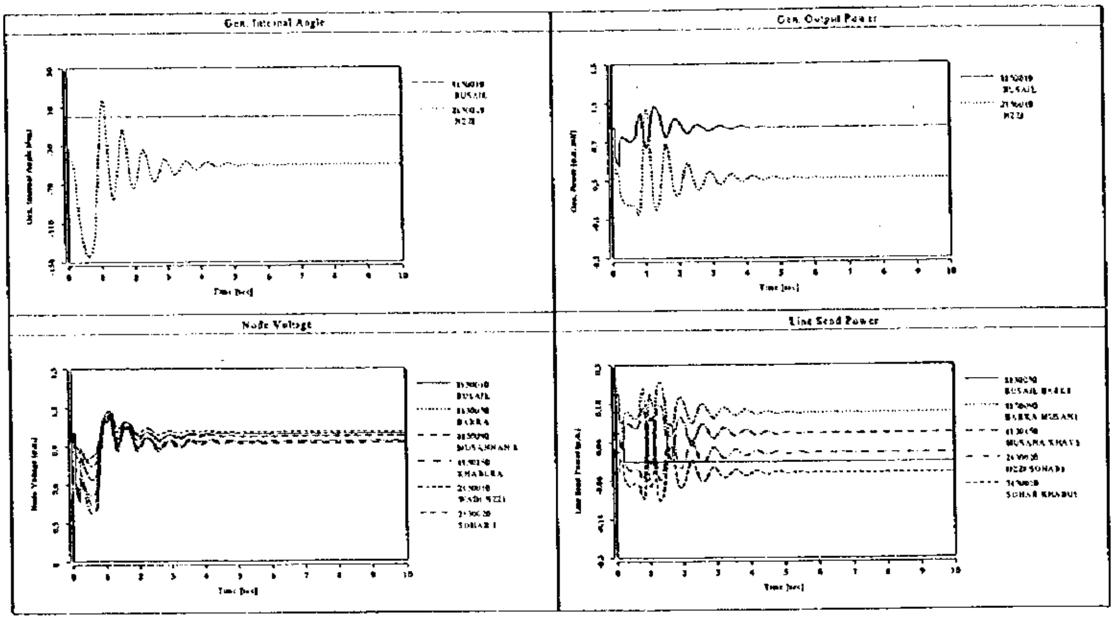
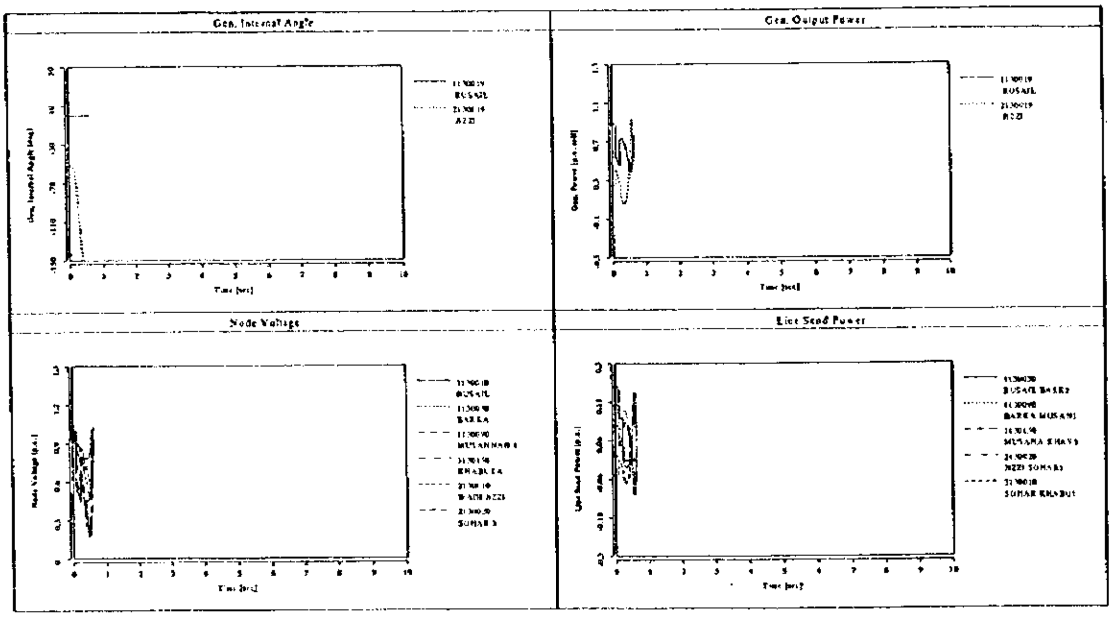


Figure S-3 Sequence of breaking an electric circuit

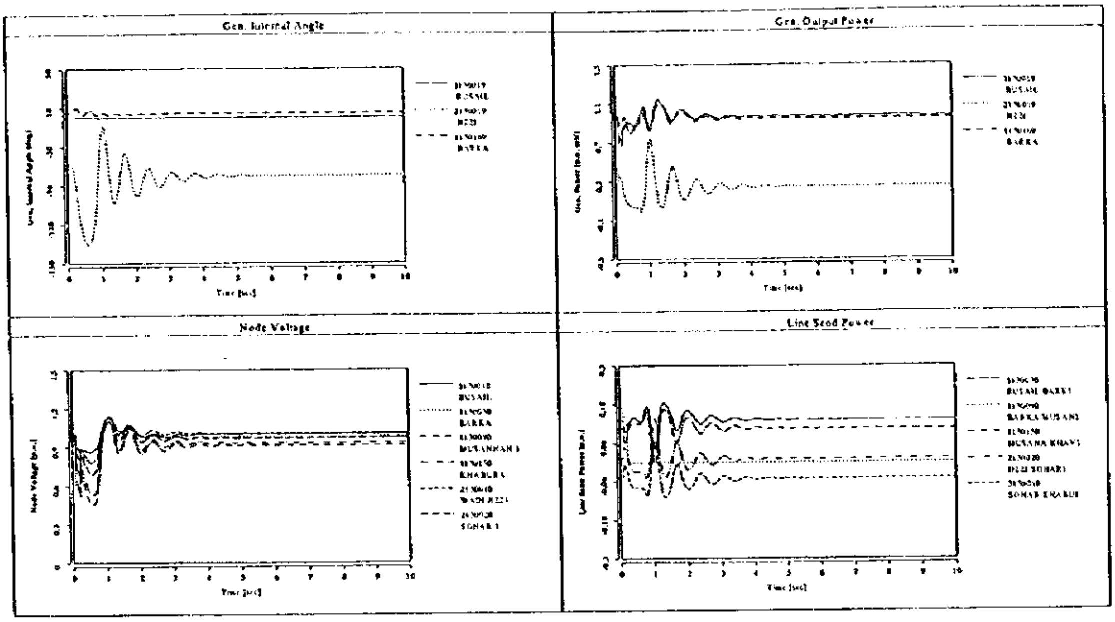


(a) Transmission Power = 173MW, T_1=6cycle, T_2=0.5sec

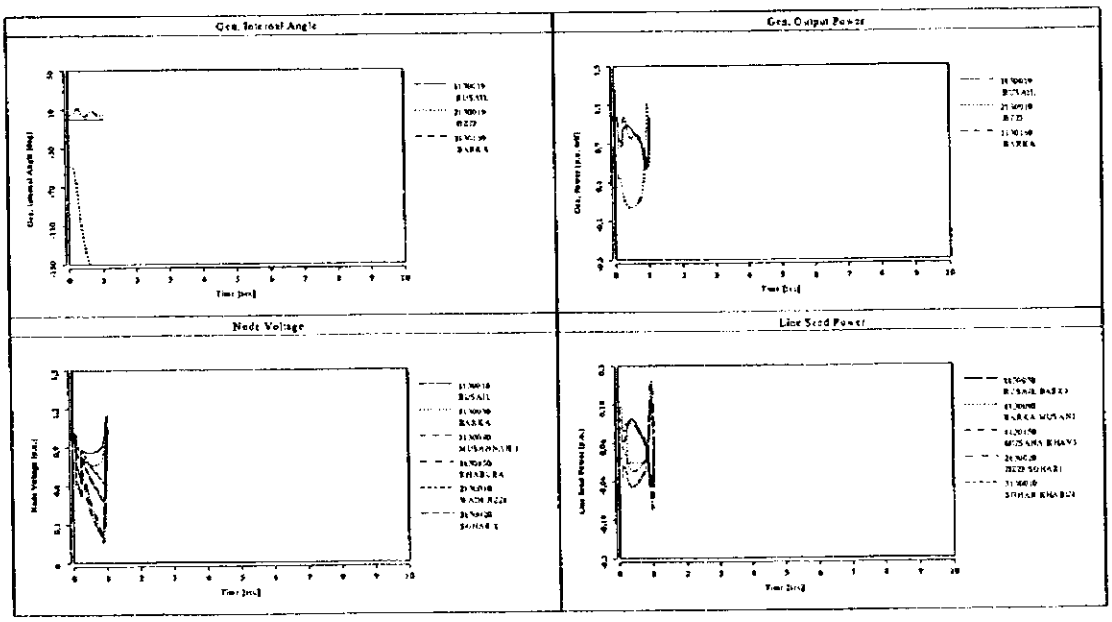


(b) Transmission Power = 212MW, T_1=6cycle, T_2=0.5sec

Figure S-4 Simulation waveform



(a) Transmission Power = 212MW, T_1=6cycle, T_2=0.5sec



(b) Transmission Power = 212MW, T_1=7cycle, T_2=0.5sec

Figure S-5 Simulation waveform (Connect Barka PS)

The diagrams show as follows :

i)If the opening time of fault point side CB is 0.12 sec [6 cycle] or less, power system is stable.

ii)If the opening time of other side CB is 0.5 sec or less, power system is stable.

iii)The limit of transmission power flow from the Musanna SS to the Khabura SS is about 170MW from the point of view of the system stability.

iv)When the Barka PS is connected, the limit will increase by about 40 MW.

With these benefits, the interconnection should be done soon. But no relief power is available now because both systems face a shortage of supply power. We recommend to interconnect the two systems by 2001, when enough power supply can be secured. It is also recommended to introduce the central load dispatching center at the same time.

5. Central Load Dispatching Center

After the initial interconnection, but before the full installation of monitoring and control functions, such as central control and remote communications, the following principles apply in the operation of integrated grid:

- Under normal conditions, both systems will balance demand and supply, as before, keeping the interconnection tie flow to a minimum.

- If a fault occurs in the Wadi Jizzi system, the system can receive relief power from the Muscat system.

The interconnection will increase the scale of system and its complexity. This, in turn, will require improvement in supply reliability and more economical system operations. In the near future, introducing a central load-dispatching center that includes, but is not limited to, the following functions, will be necessary.

- Monitoring and control of power flow
- Frequency control of systems
- Automatic control of system voltage
- Economic demand and supply adjustment
- Early recovery from system fault

Presently, however, there is no system to examine the state of demand and supply or to monitor the operations of primary power systems. Thus, there are no comprehensive plans for demand and supply control. Demand and supply adjustments help to improve the economics and reliability of power output of each power station; no one currently bears these adjustment duties. To cope with a problem, such as a tripped unit, these power stations increase the number of units operating in parallel. This is a very inefficient operation. In the future, when the system interconnection is implemented, the whole system capacity will increase further, meaning higher supply reliability and more economic operations will be required.

(1)Necessity of Economical Demand and Supply Operations

A demand and supply operation program has been developed that is easy to understand. This is a preliminary program, but it provides the basic ideas for economical operation. This program is practical and can be used for daily operation planning and evaluation, even though there is a central load dispatching center at the moment.

The ideas of this program for economical demand and supply operations are summarized below.

- The steam turbine units at Ghubrah PS for desalination and the units at Manah PS are used prior to other units. The operation of Manah units is determined by contract. (This item can be changed to make the Manah units work with other units in parallel.)

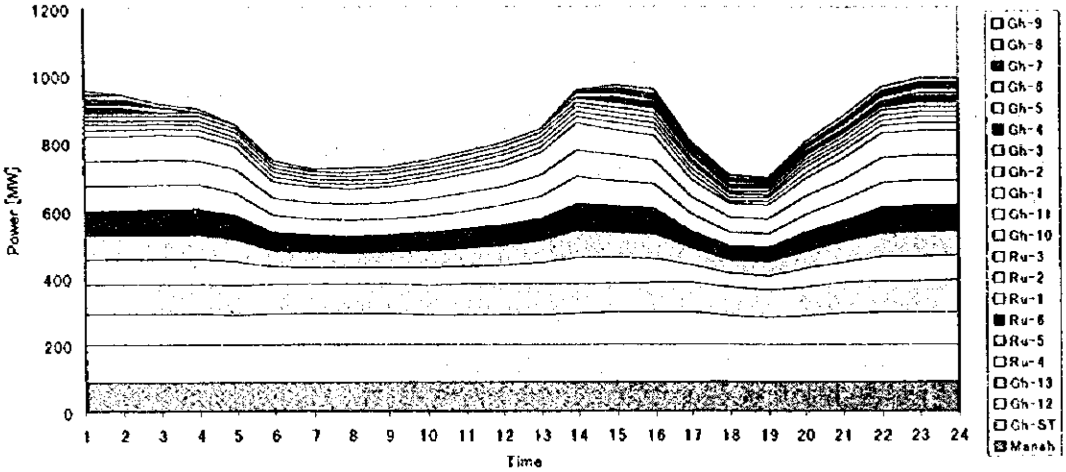
- More efficient base units (Ghubrah PS 12, 13 & Rusail PS 4~6, 1~3) continually supply full output to meet hourly demands.

- Less efficient peak units (Ghubrah PS 10, 11, 1~9) deliver output and keep the spinning reserve, which is equal to the capacity of the largest unit.

(2)Comparison of Actual versus Economical Operation

A typical summer day (1-August-1997) was selected to compare actual operations with the economical operations in the Muscat system. (Figure S-6)

Actual Operation



Economical Operation

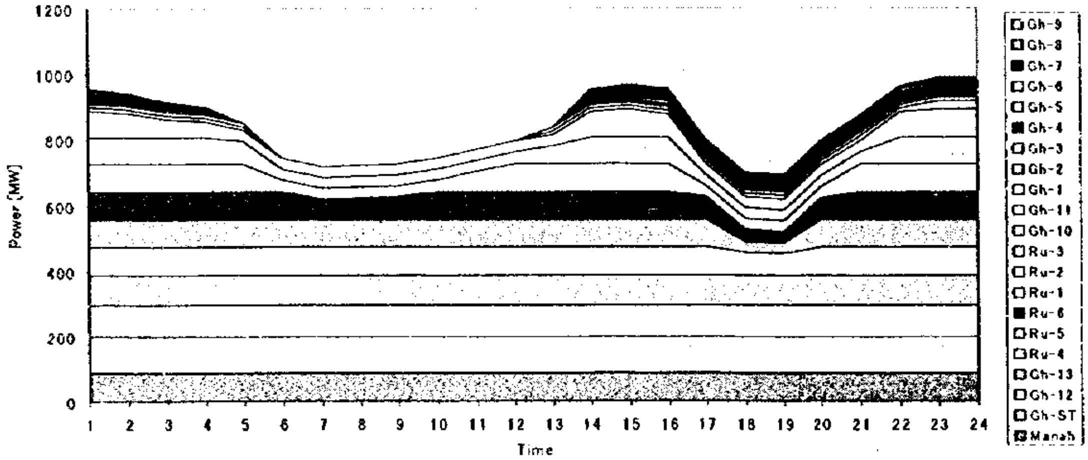


Figure S-6 Difference of Actual Operation and Economical Operation (1-8-1997)

Table S-9 Comparison actual operation with economical operation (1-8-1997)

		Actual Operation	Economical Operation
Base Units Average Output (MW)	Ghubrah PS(12,13)	90 MW	94 MW
	Rusail PS (1~6)	62	69
	Average	69	75
Average Spinning Reserve		201	159
Gas Fuel Cost / Day (1000 OR)		107.4	103.6

Compared with the actual operation, the economical operation is as follows

- The number of units in parallel can be reduced, saving 42MW of hourly spinning reserves.
- Economical operation can reduce gas fuel costs by 3.5% with a 6MW increase in the average outputs of efficient base units instead of peak units.

(3) Fuel Cost Saving by Economical Operation

Estimates of yearly gas fuel costs were examining the load-curve through typical days, such as peak season, off-peak season and days in between. With the introduction of an economical load dispatching function, the results are as follows.

During the peak season, there is no room to operate economically. Almost all units operate at full output in order to meet the high loads and the merit is about 3.5%. In off peak or middle season when the load is fairly light or load fluctuation is large, economical operation results in merits of 6~14% because more efficient units can be selected to work in parallel.

Table S-10 Fuel cost saving in different seasons

	Typical Day	Merits of Gas Fuel Cost/Day	MWh/Day
Peak Season (June~August)	1-8	3.5 %	20,300
Off Peak Season (Nov.~Apr.)	14-1	6.0%	7,500
Middle Season (May, Sep., Oct.)	1-5	14.2%	14,000

<u>Yearly Merits of Fuel Cost</u>; 20,300/12,330*3/12*3.5% + 7,500/12,330*6/12*6.0% + 14,000/12,330*3/12*14.2% = <u>7.3%</u>

The Muscat system's yearly gas fuel costs (Ghubrah PS & Rusail PS) are approximately 24,250,000 RO in 1997. The merits amount to about 1,800,000 RO.

(4)Introduction of Central Load Dispatching Center

Economical, computer-based demand and supply coordination functions, which are part of the proposed central load dispatching center, will offset required investment costs. Introducing a central load dispatching center is recommended, when the interconnection between the Muscat and Wadi Jizzi systems is completed, and system capacity increase further requiring improved supply reliability and more economical operations.

The further system capacity increase requires improved supply reliability and more economical operations. Introducing a central load dispatching center is recommended when the system interconnection between the Muscat and Wadi Jizzi systems is completed.

The economic merits of interconnection are so significant that the system interconnection should be materialized as soon as possible. For the time being, there is no emergency relief power because both systems lack enough supply power and should only be interconnected after supply power is deemed sufficient. The central load dispatching functions should be developed and expanded within the range of these merits. Detailed investigation is required to determine the necessary level of central load dispatching functions, steps for expanding functions, and required investments.

Investment cost of CLDC		4 mil RO
Reduction of fuel expenses	(7% of gas fuel)	1.8 mil RO / year
NPV of central load dispatching center	;	20.9 mil RO (2001-2018)

In summary, a recommended ten year plan on the supply side is defined in " SSM Summary Table."

SSM Summary Table (Muscat/Wadi Jizzi System)

(   ) Investment: 1000 RO

			1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Peak Demand (MW)			1596	1773	1843	1946	2046	2122	2197	2271	2344	2416	2489	2563	
Supply Capacity (MW)			1806	1930	2024	2118	2160	2243	2337	2431	2507	2595	2628	2705	
Project	Generation Expansion	Rusail PS	·GT7 (13,850) ·Water Injection (2,420)						·GT8 (13,850)			·GT9 (13,850)	·GT10 (13,850)	·GT11 (13,850)	71,670
		Ghubrah PS	·Water Injection (2,630)				·GT14 (13,850)	·GT15 (13,850)					·GT16 (13,850)	·GT17 (13,850)	58,030
		Manah PS		·GT4,5 (-----)											-
		Barka PS				·GT1 (37,400)		·GT2 (13,850)		·GT3 (13,850)	·GT4 (13,850)				78,950
		Wadi Jizzi PS	·GT12,13 (13,320) ·Water Injection (2,280)	·GT14 (6,660)	·GT15 (13,850)							·GT16 (13,850)			49,960
	·Interconnection Line ·Central Load Dispatching Center (*CLDC*) etc.		·Static Condenser (600)		·Interconnection (7,530) ·CLDC (4,000)									Battery Storage (2,500)* (not included)	12,130
Total Investment			35,100	6,660	25,380	37,400	13,850	27,700	13,850	13,850	13,850	27,700	27,700	27,700	270,740

6. DSM Promotion Program

(1) Objective of DSM Promotion

Promotion of DSM is to encourage customers to implement certain power utilization pattern for rationalizing power consumption pattern. DSM is also desirable to both the electric utilities and the customers or to the country as a whole. The measures for this DSM are as follows:

- Reduction of power load through the use of alternative energy sources;
- Load leveling on the customer side (peak cutting, peak shift and bottom-up of off peak load);
- Introduction of higher-efficiency energy utilization (energy-saving) systems;

New tariff system, special contract system and promotion organization (support organization and subsidy system etc.) are good measures for inducing customers.

(2) Specific Promotion Program

In Oman, the demand for air conditioning accounts for a large percentage of power demand. In particular, we examined design conditions of the following, by making case studies of some existing buildings, and assessed economic effects:

- Gas cooling and co-generation with gas;
- Ice thermal storage cooling system;
- Photovoltaic system.

Moreover, the promotion organizations were also studied. The findings are as follows.

(3) Gas Cooling and Co-generation System

Effects of introducing a gas cooling system, using natural gas as energy source, are expected to be energy conservation and reduction in energy cost at the consumer end. At the supply side, too, improvement of plant factor and deferral of constructing generating equipment are expected to reduce electricity supply cost. By these merits, the systems using natural gas are themes to be coped with. The results concerning the model buildings show that the gas cooling system would be more economical than the electrical system in large scale buildings.

However, in Muscat, there are high pressure natural gas supply pipelines only for the power generation plants and other limited sites. There is neither city gas supply network nor a plan for that. Therefore, in order to facilitate gas cooling in Oman, it is desirable to have a project for developing a town gas supply network in the area where electricity load density is high; office building districts and shopping centers.

Promotion program

In the Royal Hospital, the economic effect of introducing gas cooling through co-generation is large. In addition, the hospital is located very close (less than 1 km away) to the existing high pressure natural gas pipeline. Hence, the introduction of gas cooling system is easy to be introduced, and it is desirable to promote the project of Royal Hospital prior to the development of the town gas supply network.

(4) Ice Thermal Storage Cooling System

Through load leveling by the introduction of ice thermal storage cooling systems, construction of new power supply facilities can be controlled. At the same time, the capacities of power receiving facilities can be reduced. If the Time-of Use (TOU) tariff is introduced, customers can take advantage of inexpensive electricity during off-peak period.

The results of economic evaluation are as follows.

Case 1: The construction costs per kW of a gas turbine is subsidized by the Government for rewarding power (kW) reduction.

Case 2: Load leveling operation is conducted, and as for the rate for ice thermal storage operation, TOU rate system is applied.

In both cases, the NPV figures were slightly negative and they were not economically feasible.

Promotion program

It is concluded that the introduction of ice thermal storage cooling system is not economically feasible at the moment. However, the results in Case 2 are very delicate. Depending on promotional measures, Case 2 may become feasible in the future. It is recommended, therefore, to reconsider the implementation plan in the future when electricity tariff is revised and other policy measure are prepared for load leveling.

(5) Photovoltaic System

Generally the daily load peak occur during the period of maximum output of photovoltaic system. Hence, it is possible to achieve load leveling through photovoltaic (peak shaving). Furthermore, fossil fuels is substituted by energy of solar radiation, a renewable energy source. Energy resources available on earth can be saved.

With the current cost level of 3,000 RO/kW, photovoltaic system is not economical. Even when the construction cost is lowered to 500~800 RO/kW, which is the target for the near future, the investment cannot be recovered from electricity cost saving alone. However, in case of long and expensive distribution line is needed for rural electrification, off-grid photovoltaic system may be economical. For the present, if the diffusion of photovoltaic systems is to be promoted as measures for environmental protection, it will be necessary to grant a considerable amount of subsidies.

Promotion program

Early introduction of the photovoltaic systems in cities is unjustifiable and unadvisable. We, therefore, propose the following policy of introduction.

- As for introduction of photovoltaic systems in near future, rural electrification may provide an opportunity. If a long-distance distribution line is required relative to the scale of the demand, the cost will be higher. In such a case, photovoltaic systems may be used.

- In the distant future, the construction costs of photovoltaic system will be reduced. Environmental benefits will be added. At that time, introduction of photovoltaic systems may become feasible even in cities. Hence, the diffusion of photovoltaic systems in electrified areas for the sake of energy conservation and environmental conservation should be studied continuously.

(6) Organization for DSM Promotion Program

To facilitate and accelerate individual DSM promotion program with the objective of optimal DSM promotion, an organization dedicated to promote DSM is necessary. The more DSM is implemented, the more the whole country benefits. The point is how to educate consumers and provide incentives. The organization will play a major role in public relations, education and consulting.

7. Proposals for Financial Soundness

The power supply business has a large amount of deficits every year, and the loss has been offset by government subsidy so far. However, such a situation is not sound. It is, therefore, an urgent task to improve the profitability of the business and balance its revenues and expenditures. The Government has revealed the policy of accelerating the privatization of the electricity business. In order to go ahead with the privatization, it is definitely necessary to improve profitability. In this regard, we would like to propose the following measures:

(1) Conversion from Diesel Oil to Natural Gas

The higher costs of diesel generation in rural areas result in a huge amount of losses. It is needless to say that replacing old diesel generators with new efficient generators, gas turbine generators for example, is extremely important. With this understanding, MEW has been tackling this problem and planning the construction of gas turbine power stations in the Dhofar and Sharquiya regions with the initiative of the private sector.

(2) Improvement of Load Factor

The heavy electricity demand for air conditioning has caused a fundamental problem of low load factor in Oman. The gap between the summer season and the winter season is very large. Because of this problem, the power plants only operate at only 50% of their capacity. It is very difficult to deal with this discrepancy in demand. However, the best effort must be made to improve efficiency of operation by reducing the peak demand and increasing the base load during low load operation. The methodology of DSM is useful to reduce peak demand.

(3) Improvement of Thermal Efficiency

The thermal efficiency of power plants is not good because the present operation method is not systematized. It is possible to improve the thermal efficiency through an integral planning and operation of turbines. For that purpose, we would like to propose the following measures:

① Interconnection between the Muscat system and the Wadi Jizzi system

② Construction of a central load dispatching center and operation of turbines with an economic load distribution program

In addition, operation and maintenance of all the main power stations in the northern grid have been consigned to private companies by contract for 3 to 4 years. According to the contracts, fuel, spare parts, electricity and water for home use are supplied by MEW. The biggest concern of operators is how to avoid accidents and power failures, and how to keep the stable operation of the power station. They usually do not pay much attention to improvement of thermal efficiency. Therefore, we would like to propose that MEW plan some incentive schemes for paying back a certain portion of reduced costs to operators, so that they will make efforts in reducing fuel costs.

(4)Reduction of Losses

According to the Annual Report 1997, the net system loss, excluding plant in-house use and desalination, amounts to 16.9% (1,234 GWh). That is an increased of 0.8% (141 GWh) from 16.1% (1,093 GWh) in 1996. The loss rates (loss at transmission and distribution) in advanced countries are less than 8% (1995). In Japan, the Unite States and Germany the losses are around 5%. Since the reduction of loss leads directly to an increase of revenue, more and more emphasis should be put on this point. Regarding loss management, MEW has already launched measures for improvement, and as the first step, it is going to measure the amount of losses by replacing meters at power stations.

In addition, according to the recent operation records at power stations, there are significant differences of between 2-10% in the volume of natural gas purchased from PDO. Fuel consumption is the largest portion, 44%, in the production cost. Keeping accurate records is extremely important in cost management. It is necessary to calibrate meters as soon as possible and also at regular intervals.

(5)Reduction and Deferral of New Investment

According to the Annual Report 1997, the depreciation and financing costs of fixed capital came to 36.2% of the total production costs. We would like to propose the following two measures in order to reduce new investments, which will eventually contribute to lower fixed costs.

①Interconnection between the Muscat system and the Wadi Jizzi system
②Increasing the outputs of existing gas turbines by water injection
③Promotion of DSM

(6)Restructuring of Tariff System

It will take a long time to eliminate the deficits through cost reduction alone. It seems inevitable to also pursue restructuring of the tariff system to increase revenue. Raising electricity tariff is unavoidable. In changing the current tariff, expected impacts to the general public should be carefully examined. In Oman, industrial users are very limited. About 80% of electricity consumption is charged with the residential tariff. It is, therefore, very important to analyze how to revise the residential tariff.

① Tariff Reform

To achieve substantial revenue increase and not to affect lower income families, it is recommended to lower the threshold of the first-stage residential rate, 3,000kWh per month, to 2,000kWh per month. By this change, the current rate of 10Bz/kWh goes up to 15Bz/kWh for the consumption between 2,000 to 3,000 kWh per month, the total of which is 520 million kWh, or 16% of the total residential demand. The expected revenue increase will be about 2.6 million RO per year. The number of households and government offices to be affected by this change would be 50,000 to 60,000 depending on many conditions such as the temperature in the summer season. Changing other thresholds would only generate minimal revenue increase, because the electricity consumption which is charged higher rates is very small.

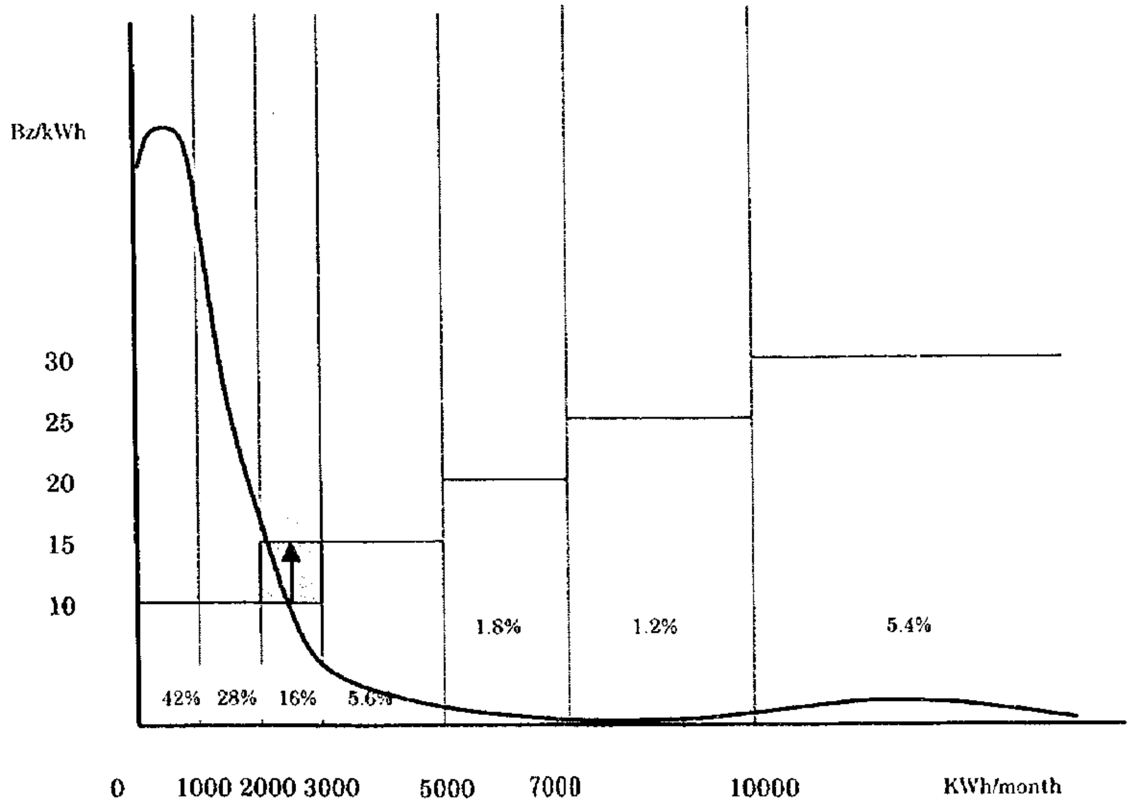


Figure S-7 Consumption profile and overview of proposed tariff

In addition, a small fixed charge of 1RO per month is also recommended. This fixed charge will be applied to all the customers. The expected revenue increase by introducing a 1RO fixed charge will be 4.5 million RO. If this fixed rate is applied only to households, the revenue increase would be 3.5 million RO.

Table S-11 New Residential Tariff (draft)

Proposed Tariff		Current Tariff	
Fixed Charge	1 RO/month		
Consumption Charge			
0-2000kWh	10Bz/kWh	0-3000kWh	10Bz/kWh
2001-5000kWh	15Bz/kWh	3001-5000kWh	15Bz/kWh
5001-7000kWh	20Bz/kWh	5001-7000kWh	20Bz/kWh
7001-10000kWh	25Bz/kWh	7001-10000kWh	25Bz/kWh
10000kWh over	30Bz/kWh	10000kWh over	30Bz/kWh

②Special contract system for load leveling

Special contract programs can be introduced to improve the load factor, and to reduce the costs of power supply eventually. Electricity price discount will be rewarded for users who can contribute to load leveling. These programs, which are common in developed countries, would be also applied to large-scale users (cement, chemical, textile, etc.). The rationale here is to give financial incentives to customers who will contribute to peak shaving and/or peak shifting. The load leveling effort will help MEW reduce their future investment as well, but at the same time the customers will benefit from the discount. Both MEW and customers will share the benefits.

In Oman, there are few large-scale customers. It would be easy to pick out potential large-scale customers who will be able to change their consumption pattern. The detailed examination on how they use electricity is required before formulating contents of new contract. There will be various ideas on the form and amount of financial incentives. Some basic ideas for the special contract system are shown below:

- Discount for high load factor users
- Discount for changing operation hours
- Discount for accepting load shedding in case of power shortage

③Metering

The potential problems associated with electricity meters are illegal tampering and measurement errors. Both forego electricity revenue, and hence MEW must take appropriate measures to deal with them.

a. Tampering

There are several different ways of meter tampering which have been all identified by MEW. Most of them are simple, and easily found by checking meters cautiously. In most cases, tampering seems to be suspended a few days before the day of meter reading. To cope with this problem, it is recommended to make a surprise visit to customers occasionally and also to develop computer software which can pick out suspected cases. MEW and OIFC should discuss these issues and revise the current contract as needed.

b. Error due to wear

From the results of testing old (being used for more than twenty years) meters, it can be said that many old meters still show good record. On the other hand, some meters have more than 10% negative error. It is estimated that there are about 50,000 meters, 15% of total accounts, which are used for more than twenty years in Oman. If we assume that those old meters have 4% negative error on average, the foregone revenue every year would reach 500,000RO; 0.6% of the total revenue.

It is not feasible to check every old meter because a lot of time and money are required. The only viable solution is to replace all old meters with new ones. If MEW is going to replace 10,000 old meters every year at their expense, annual budget of 200,000RO is needed. After five years, the foregone revenue will be fully recovered. This project, replacing old meters, is strongly recommended because its Net Present Value (NPV) over the next twenty years is 2.85 million RO.

8. Policy Recommendations

The stable supply of electricity is essential to industrial development and better life in every country. In Oman, electricity consumption is expected to grow by 5% annually due to the strong and growing economy. Investments in power generation and transmission should be made continuously without interruption. There are, however, some problems in the electricity supply such as shortage of generation and transmission capacity, and revenue shortfall, which need to be resolved as soon as possible. With a fundamental understanding on the importance of electricity supply for the future development of Oman, MEW is recommended to implement the following plans and programs to improve both demand and supply of electricity.

(1) Power Development Plan

The power development plan should be disclosed to the public. It should be revised annually considering the demand growth and big development projects. The plan serves as a basis for investments which must be made in a timely manner to secure enough capacity. At the same time, private investment projects will be accelerated because the prospects of electricity supply, which is an important factor in large-scale industrial projects, would become clear.

(2) Energy Conservation Center

Among DSM measures to curtail electricity demand for air conditioning, energy conservation cannot be ignored. Moreover, it is the only item which can be started immediately, The ideas for energy conservation include not only raising room temperature, but also some technical measures such as improving efficiency of equipment by providing adequate maintenance or replacing old units. These measures, if applied nationwide, would significantly contribute to the electricity supply by cutting down peak demand. In order to undertake the measures, an organization which specializes in educating the public and also in providing the technical services. At the same time, this organization should oversee some mid-term issues such as gas cooling or ice thermal storage.

(3)Cost Reduction Effort

In the long run, raising electricity tariff would be inevitable. It is, however, important to make utmost efforts on cost reduction. For this, the consciousness on costs should be stressed among the people working for the electricity service. Furthermore, it is advisable to introduce incentive measures to operators and other related entities to reward them when they generate ideas and achieve significant cost reduction.

(4)Building Database

It is necessary to monitor actual electricity consumption at many sample customers to accumulate data for tariff reform and DSM promotion. By using such a database, it would become possible to develop concrete programs and also to make an assessment on their effects.

(5)Technical Training

Development of technical capabilities within MEW is important to reduce reliance on outside consultants. With sufficient technical knowledge, MEW staff can make decisions very quickly. Overseas technical training program may be effective as a short-time capacity development.

(6) Comprehensive Energy Planning

Coordination between electricity and natural gas is important to achieve "Best Mix" in comprehensive energy planning in Oman. For example, district cooling system or co-generation, which use natural gas directly, is more efficient, and hence, such projects should be promoted where feasible. To facilitate these projects, it is strongly recommended that MEW and MOG (Ministry of Oil and Gas) regularly discuss on various energy issues.