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Time of Use Electricity in Thailand

by

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1. Introduction

The TOU tariff was first implemented in Thailand in 1964. At that time, the TOU rate was applied on a very small scale as an option for MEA's business and large industry customers[1].

Before the TOU option was introduced, the business and large industry customers were under the two parts tariff scheme with three declining blocks of demand charges and four declining blocks of energy charges that are based on the customer's load factor (see Table 1). Under the TOU option, the business and large industry customers may choose to remain under the

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[1] In 1964 the MEA customers were classified into residential; small residential; business and small industry; business and large industry; business and large industry (off-on peak); water utilities; and street lighting.

same classification or they may request for the off-on peak classification. However, there were only three customers that requested for the TOU option.

The Yanhee Electricity Authority, later merged with the Lignite Authority and the Northeast Electricity Authority to become EGAT in 1968, introduced a TOU rate for its direct customers in 1966 (see Table 2). There were two options available for EGAT's direct customers. The first option is the off peak category which allows power usage only during the off peak period. In the second option, a customer is allowed to use power during the peak as well as the off peak period but must not let his maximum demand during the peak period exceed the maximum demand during the off peak period by more than 25 percent. Under the second option, the off peak rate applies to the off peak period and the industrial rate applies to the peak period. There is, however, only one customer, the Siam Cement Company (Tha Luang) that requested for this option.

After 1966, the TOU rates were adjusted several times but the options for MEA and EGAT's customers were retained until 1987 when there was a major revision in the overall tariff structure. In the 1987 tariff revision, the TOU structure was also proposed and accepted in principle but the option was not implemented at that time. Customers under the original TOU option were relegated to the large manufacturing and mining group. The TOU proposal in 1987 was modified and finally implemented in January 1990 for all of the large manufacturing and mining customers. This customer group's energy consumption accounted for 13 percent of all MEA customers' energy consumption and 20 percent of all PEA customers' energy consumption in 1989. It was agreed by the subcommittee on energy policy formulation to monitor the TOU tariff for a one year period. The rate then will be evaluated as to its effectiveness as well as to study the feasibility of extending the TOU tariff to other customer groups.

Table 1 Comparison between TOU and One Period Tariff for MEA Mea Business and Large Industry Customers, 1964

One Period Tariff	**Demand Charge**	**Energy Charge**	
first 50 kw	38	first 50 kwh/kw	0.40
next 150 kw	34	next 150 kwh/kw	0.38
over 200 kw	30	next 200 kwh/kw	0.32
		balance	0.25
TOU Tariff			
Off peak (20.30 - 28.30 hour)	30		0.19
On peak (18.30 - 20.30 hour)	80		0.19

Energy charge in baht/kwh/kw

Demand charge in baht/kw

Source : Thailand Power Tariff, B.E. 2488-2522. Tariff Section, Power Economic and System Operation Planning Division, System Operation Department, Electricity Generating Authority of Thailand, September, 1979.

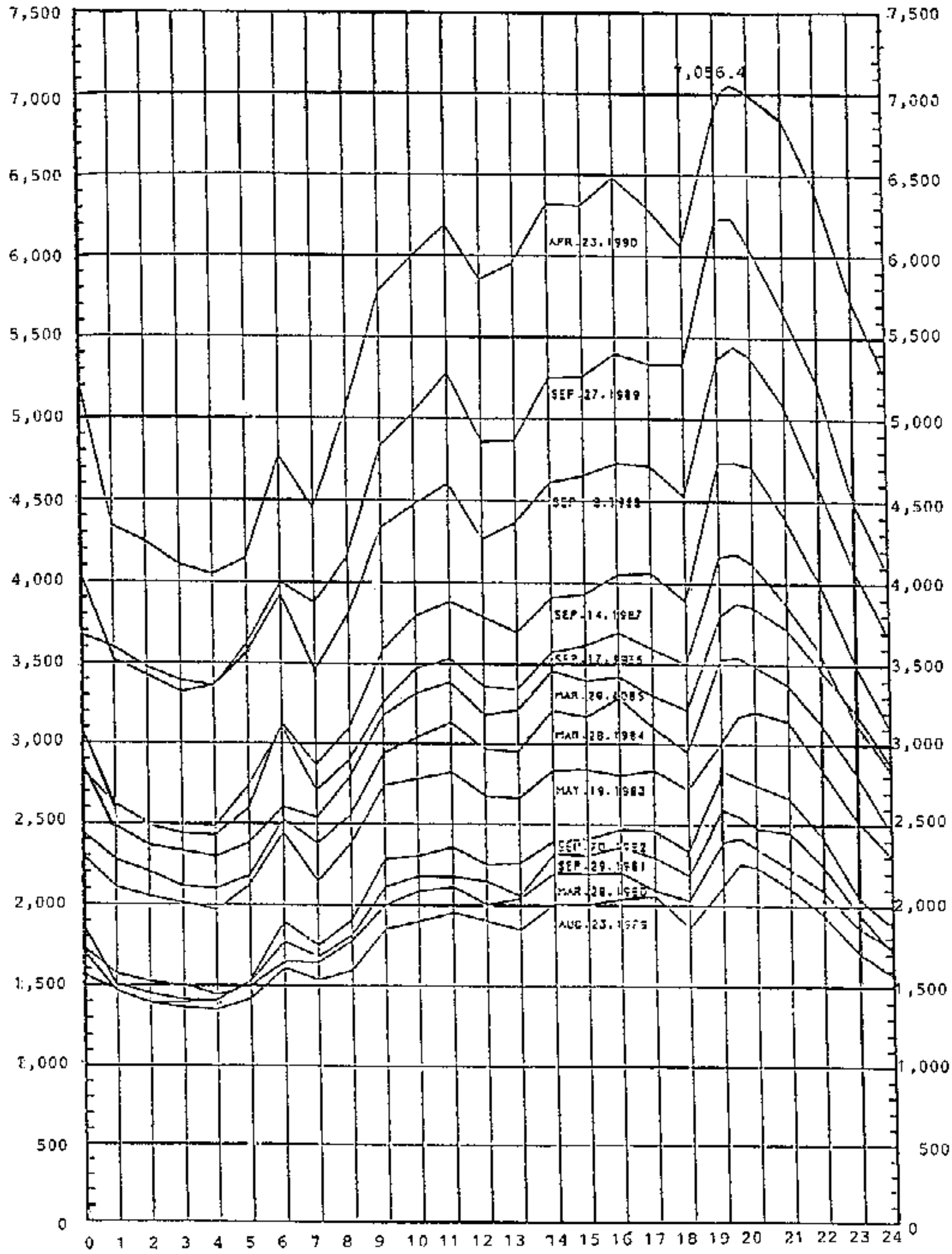
Table 2 Comparison between ROU and Industrial Tariffs for EGAT's Direct Customers, 1966

TOU Option	Demand Charge	Energy Charge	
a) Off Peak	20	0.19	
(20.30 - 18.30 hour)			
Sale to Siam Cement (Tha Luang)*			
b) Industrial Rate	40	first 160 kwh/kw	0.30
		next 200 kwh/kw	0.24
		balance	0.15
Sale to Jalapratan Cement; RID; and Sattahip Naval Station			
Flat Rate			
Sale to Siam Cement (Thuang Song)			
Normal Rate			
first 16000 kw		first	
or less	180,000 baht	500,000 kwh	0.30
pver 17-- lw	30	next	
		1,500,000 kwh	0.23
		balance	0.19
Sale to Chemferco Plant			

*Classified under the industrial group before 1966.

Figure 1 EGAT RECORDED DAILY LOAD SURVEYS ON PEAK DAY

(FISCAL YEARS 1979-1990)



2. Benefits Desired

Influeneced by a recovery in the world economy, the Thai economy expanded rapidly during the last half of the 1980s. The rapid economic growth induced sharp increases in the electricity demand (Table 3). Although the elasticity of electricity demand with respect to GDP declined slightly towards the end of the decade, demand or electricity still increased by over 10 percent per annum. The unexpected growth in electricity demand exerted pressure on the system capacity and thus the reserve margin.

Figure 1 shows the system daily load curve for a peak day from the period 1979 through 1990. It may be observed that there were no significant changes in the load characteristics even though the curve shifted up more rapidly towards the end of the decade. As a result, the system laod factor remained rather constant at around 67 percent during 1985 through 1989.

On examing the load duration curve, it is seen that there are potentials for shifting some of the load during the peak period to the other periods. The benefits of load shedding may be induced by a suitable TOU tariff and the resulted net benefits may be gauged in term of the cost/benefit framework.

3. Review of the 1990 TOU Tariff

Peak, partial peak, and off peak are the three periods under the 1990 TOU tariff that applies only to the large manufacturing and mining customers. The rationale behind such a division may be explained by examining the daily load duration curve for MEA, PEA, and EGAT (Figure 2).

Figure 2 Daily Load Curve of MEA, PEA and EGAT, 1989

Table 3 Economic Growht, Electricity Demand and Capacity, 1985-1989

Year	LF	GGDP	ED*	E	IC	R**	E
1985	68.75	3.5	3878.4	23356.57	6459.73	2581.33	2.7
			(9.33)	(10.87)		(66.6)	
1986	67.66	4.5	4180.90	24779.53	6637.23	2457.0	1.7
			(7.80)	(6.09)		(58.8)	
1987	67.99	8.4	4733.90	28193.16	6886.65	2152.75	1.57
			(13.23)	(13.78)		(45.5)	
1988	67.04	10.4	5444.00	31996.94	6916.30	14723.3	1.4
			(15.00)	(13.39)		(27.0)	
1989	66.59	9.5	6232.70	36457.01	7282.86	1050.1	1.5
			(14.49)	(13.94)		(16.8)	

* Figures in parenthesis are growth rate

** Figure in parenthesis are percent

LF = load factor

GGDP = growth rate of GDP

ED = maximum demand

E = energy demand

IC = installed capacity in MW

R = reserve margin

E = maximum demand elasticity with respect go GDP

Source : EGAT Power Development Plan 90-02. Report number 10600-3311, Volume 1, Systems Planning Department, EGAT, 1990.

The peak period is from 18.30 hour to 21.30 hour and coincides with the PEA peak demand. The MEA peak demand occurs in the afternoon during the partial peak period which runs from 8.00 hour to 18.30 hour.

The load starts at 4000 MW around 8.00 hour and rises sharply to 5200 MW at 11.30 hour and then dips slightly before rising gradually to 5300 MW at 18.30 hour, the beginning of the peak period. During the peak period the load increases sharply again to 6300 MW at 19.00 hour and then tapers off to 5500 MW towards the end of the peak period at 21.30 hour. Thereafter, the load falls sharply to a trough of 3300 MW around 4.00 hour before it gathers momentum and rises to 4000 MW at 5.30 hour. The load then drops slightly before rising again into the partial peak period.

It may be observed that the load characteristics of MEA and PEA are rather similar during the partial peak period up to 15.30 hour. Then, the PEA load increases sharply towards the end of the partial peak period and the beginning of the peak period.

In the previous load patterns study, the peak demands of the residential, specific business, large manufacturing and mining, and special rate customers were shown to be the major components of the system peak[2]. The energy consumption of these groups accounted for about 37 percent of all MEA customers energy consumption and 50 percent of PEA customers' energy consumption. This lends support to the application of TOU tariff to the large manufacturing and mining customers.

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[2] See Vichit Lorchirachoonkul and Thiraphong Vikitset Report on Load Patterns Analysis of MEA and PEA customers. National Institute of Devleopment Administration in Association with Monenco Consultants Limited Funded by Canadian International Development agency, 1990

In the TOU tariff, the demand charge during the peak period shoud be consistent with the 1987 demand charge for this customer group until the 1987 tariff structure is revised. In this framework, the demand charge should be set at 170 baht/kw-month for the peak period and energy charge at 1.22 baht/kwh for all the three periods[3]. However, the demand charge for the peak period was set at 180 baht/kw-month to offset the fall in the power authorities' revenue under the TOU scheme (Table 4). A demand charge of 90 baht/kw-month was set for the partial peak period to reflect MEA's marginal cost. However, in order to avoid double counting, the partial peak demand charge applies only to demand in excess of the maximum demand during the peak period. There is no demand charge for power usage during the off peak period since a marginal increase in demand during this period does not exert pressure on the system capacity.

4. Evaluating of TOU Tariff

4.1 Net Benefit to a Customer

The net benefit of the TOU tariff to a Consumer depends upon the meter cost, administration cost, his price response and the costs of adjustment to the tariff. Consider an electricity customer requiring a given amount of electricity for his production process as represented by the production isoquant in Figure 3(a). This customers demands KWH1 of electricity at the effective tariff rate of T1 baht/kwh in association with the other factors of production at point A to produce an output of Q1.

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[3] The gas/fuel oil fired power plant is the marginal plant for all the three periods in the 1987 tariff structure.

Table 4 TOU Tariff for Large Manufacturing and Mining Customers, 1990

Period	Demand Charge (baht/kw-month)	Energy Charge (baht/kwh)
peak (18.30 - 21.30 hour)	180	1.22
partial peak (8.00 - 18.30 hour)	90	1.22
off peak (21.30 - 08.00)	0	1.22

Notes : 1. Demand charge during the partial period applies only to demand in excess of maximum demand during system peak.

2. There is a four percent discount on the total electricity bill.

A change in the tariff to T2 baht/kwh causes an expansion, ceteris paribus, in the minimum cost output under the same expenditure to !2 at point B where the required electricity input is KWH2[4]. Denmand for electricity may be derived from Figure 3(a) and shown in DT in panel (b). If the tariff reflects the marginal costs of electricity the net benefit induced by a change in the tariff from T1 to T2 is the area ABT1T2 under the demand curve DT in Figure 3 (b). The net benefit is the result of the substitution of electricity for other factors of production (A **Figure 3** Net Benefit from a Change in Tariff)

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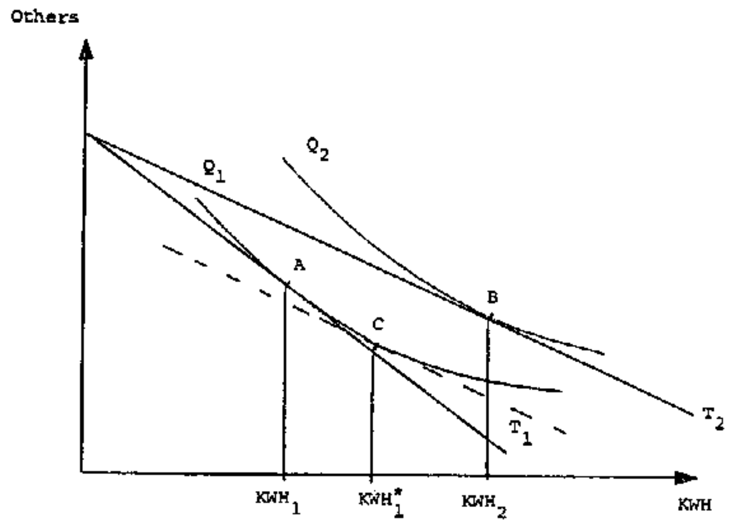
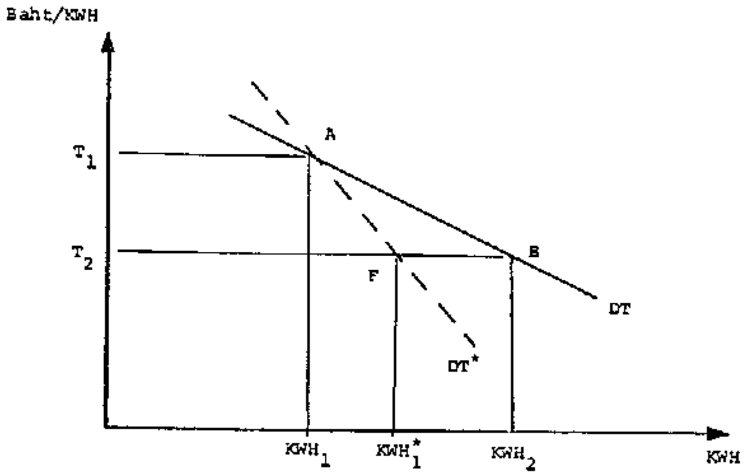
[4] Point B is not necessarily the profit maximizing output which depends upon the demand for the customer's output.

Figure 3 Net Benefit from a Change in Tariff



(a)



(b)

to C in panel a) due to a change in their relative prices, and the expansion in output (from C to B in panel a) due to an apparent increase in the customer's expendigure.

Since the major objective of the TOU tariff is to induce a shift of electricity demand from the peak period to other periods and not to promote expansion in the customer's production it may be argued that the net benefit be evaluated only in terms of the substitution effect. The demand curve with only the substitution effect is thus the dotted line DT* in Figure 3 (b) and the net benefit of the change in the tariff is the area AFT1T2.

To simplify the analysis, it will be assumed that, in the short run, a customer is not able to substitute electricity for other factors of production. The production isoquant under this assumption is shown in Figure 4 (a) and the demand for electricity with only the substitution effect is shown as the dotted line D* in panel (b) of the same figure. The net benefit associated with a tariff change form T1 to T2 is the area T1T2KS.

Under the TOU tariff, a change in the effective tariff rate from T1 to T2 is caused by substitutions of energy required in different periods. Although the total amount of energy requirement remains constant under the above assumption, a customer may shift a given amount of electricity, for example, from the peak period to the off peak period. Although the toal amount of energy requirement remains constant under the above assumption, a customer may shift a given amount of electricity, for example, from the peak period to the off peak period. The nature of energy substitutions between periods and the associated net benefit from the change in the effective tariff rate is shown below.

Let DC_p = demand charge during peak period

DC_{pp} = demand charge during partial peak period

DC_{op} = demand charge during off peak period

Ed_p = energy charge during peak period

E_{cpp} = energy charge during partial peak period

EC_{op} = energy charge during off peak period

t_p = number of hours in peak perod

t_{pp} = number of hours in partial peak period

t_{op} = number of hours in off peak period

Kw_i = kilowatt demand during the ith period, I = p, pp, and op

KWH_i = kilowatthour consumption during the ith period, I = p, pp, and op

and DC_p DC_{pp} D_{cop}

EC_p EC_{pp} DC_{op}

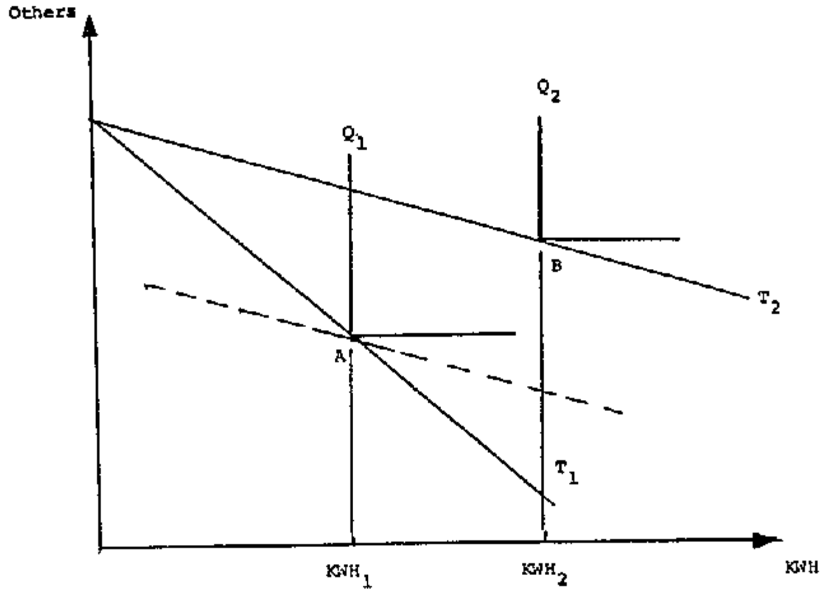
Total $KWH = KWH_p + KWH_{pp} + KWH_{op}$

Under this tariff structure, the cost of a KWH demanded by a customer may be expressed as

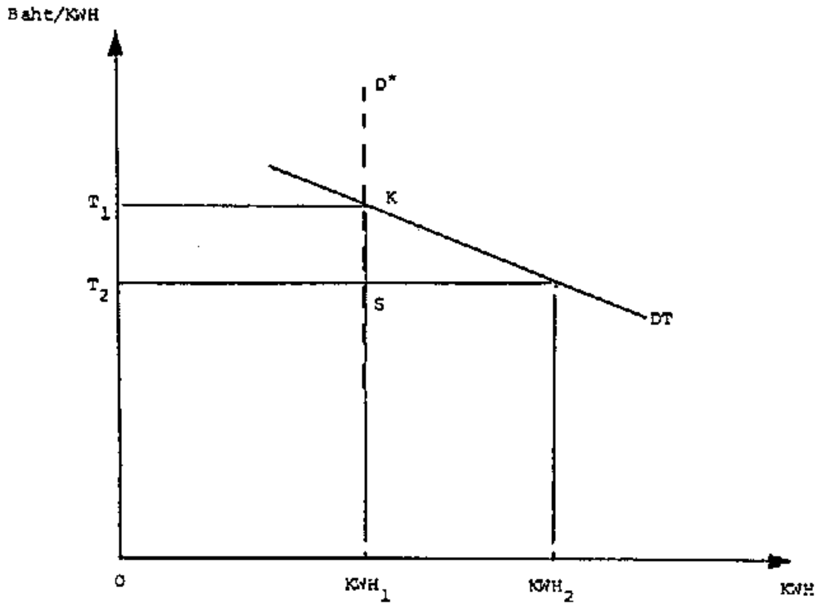
$$(1)\quad C = EC_p KW_p + EC_{pp} KWH_{pp} + EC_{op} KWH_{op} + DE_p KW_p$$
$$+ DC_{pp}\max[0, \min(KW_{pp} - KW_p)]$$
$$+ DC_{op}\max[0, \min(KW_{op} - KW_p, Kw_{op} - KW_{pp})]$$

As an illustration of net benefit estimation, consider a customer with a load pattern in Figure 5 (a) where $Kw_p > Kw_{pp} > Kw_{op}$ and production isoquant in Figure 4 (a). Initially, let point A in Figure 4 (1) be the equilibrium point of this customer. The cost of electricity to this customer is the area OT1KKWH1 in figure 4 (a) or

Figure 4 Net Benefit From a Change in Tariff With No Substitution Effect



(a)



(b)

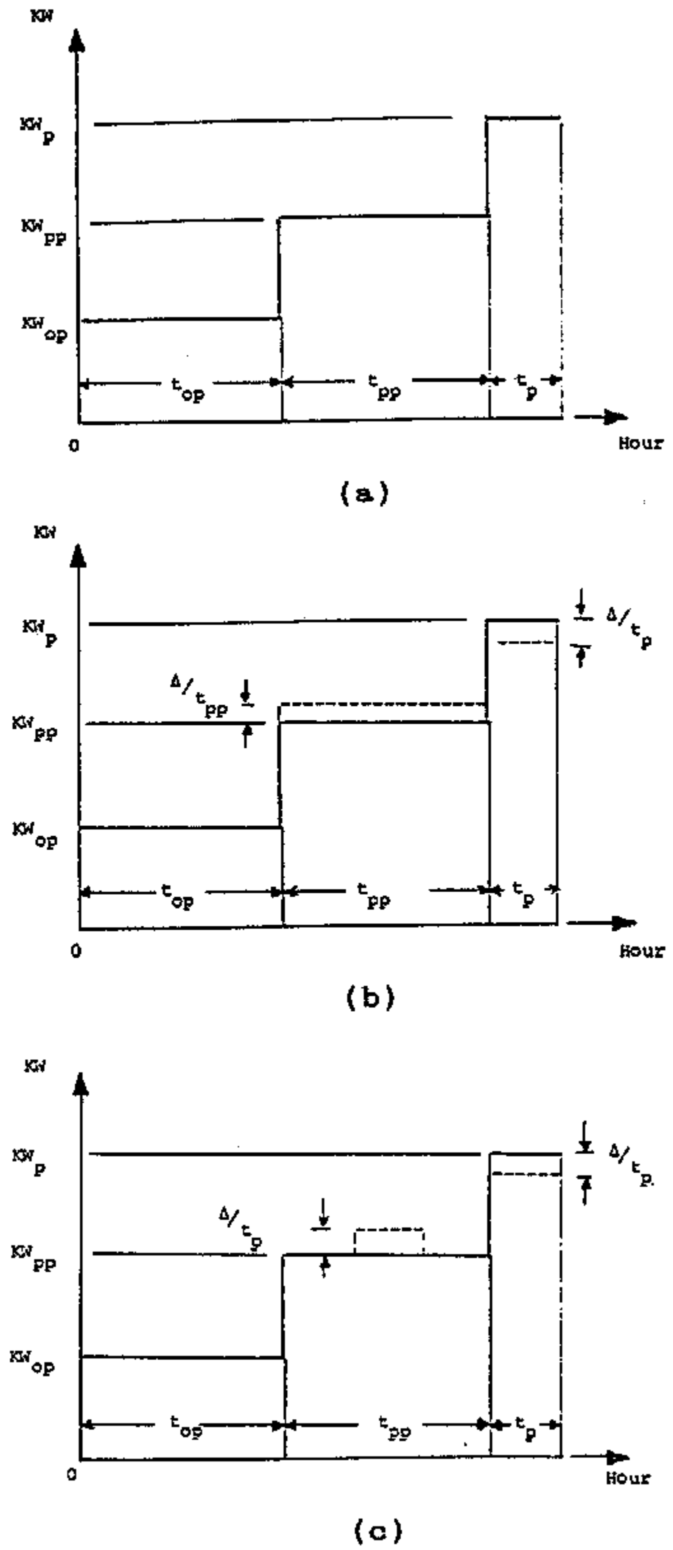
$$(2)\ C = EC_p\, KWH_p + EC_{pp}\, KWH_{pp} + EC_{op}\, KWH_{op} + DC_p\, KW_p$$

and the effective tariff rate, T1, is simply C/KWH1 bhat/kwh.

An infinitesimal shift of Δ kwh from one period to another period will alter the effective tariff rate and effect the cost of electricity to this consumer. To illustrate, consider a sift of Δ kwh from the peak period to the partial peak period with result in a corresponding reduction of Δ/tp kw demand in the peak period. There may be a minimum increase in kw demand of Δ/tpp in the partial peak period which is the lower limit if this customer is able to spread the increase of Δ kwh evenly in this period. This is shown as case A in Figure 5 (b). In the other extreme, the entire amount of Δ/tp kw may be shifted from the peak period to the partial peak period which is the upper limit and shown as case B in panel (c) of Figure 5. Under the adopted anlytical framework, it is assumed that the condition Kwp>Kwpp>Kwop still holds after the energy shfit from the peak period to the partial peak period. In some cases, demand during the partial peak period may be greater than demand during the peak period after the energy shift has taken place. However, it may be shown that the marginal benefit of energy shift in this case is less thatn the marginal benefit where the condition Kwp>Kwpp>Kwop remains unchanged.

The electricity cost to this consumer under case A and case B after a shift of Δ kwh from the peak period to the partial peak period may be written as

Figure 5 Energy Substitution Between Periods



(3) $C^* = ECp(KWHp - \Delta) + ECpp(KWHpp + \Delta) + EcopKWHop + DCp(Kwp - \Delta/tp)$

The change in the electricity cost is thus

(4) $C - C^* = Ecp - Ecpp + Dcp/tp$

and the marginal benefit is

(5) $d(C - C^*)/d\Delta = Ecp - Ecpp + Dcp/tp$

Applying the 1990 TOU tariff structure where Dcp = 180 baht/kw-month, Ecp = Ecpp = Ecop = 1.22 baht/kwh, tp = 91.25 hours/month and tpp = top = 319.375 hours/month, the marginal benefit of shifting kwh from the peak period to the partial peak period is 1.973 baht/kwh for case A and case B[5].

The illustration in Figure 5 is only one of the six possible patterns of energy consumption jnder the three period TOU tariff. The six patterns of energy consumption may be characterized by the order of kilowatt demand in each period as

Pattern 1 : Kwp > Kwpp > Kwop

Pattern 2 : Kwp > Kwop > Kwpp

Pattern 3 : Kwpp > Kwp > Kwop

Pattern 4 : Kwpp > Kwop > Kwp

Pattern 5 : Kwop > Kwp > Kwpp

Pattern 6 : Kwop > Kwpp > Kwp

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[5] In the 1990 TOU tariff there is an additional four percent discount on the total electricity bill.

There are incentives for a customer to shift a given amount of energy from the peak period to the partial peak period from the peak period to the off peak period, from the peak period to the partial peak and off peak period., and from the partial peak to the off peak period. Since demand charge in the peak period is greater than demand chages in the peak and off peak periods the other directricity cost or negative marginal benefit to the customer.

The marginal benefits from energy shfits between the three periods are derived fro the above six load patterns under a general three period TOU tariff in Appendix A. The 1990 TOU tariff rates are then applied and the resulted marginal benefits are presented in Table 5.

It may be observed that the marginal benefit of the 1990 TOU tariff ranges fro zerio to 1.973 baht/kwh. The differences in the marginal benefit between each scenario in Appendix A stems from the differences in the load consumption and the direction of energy shift. The marginal benefit is highest at 1.973 baht/kwh for a customer with load characteristics under pattern 1, 2, and 5 and shifting energy from the peak period to the partial and/or off peak period. There are, however, no incentives for this customer to shift energy from the partial peak to the off peak period.

Table 5 Marginal Benefits From Energy Shfit between Periods Under 1990 TOU Tariff

Unit : baht/kwh

Load Characteristics	Direction of Energy Shift					
	P to PP		P to OP		PP to OP	
Case	A	B	A	B	A	B
Pattern 1 : $Kw_p > KW_{pp} > KW_{op}$	1.973	1.973	1.973	1.973	0	0
Pattern 2 : $Kw_p > KW_{pp} > KW_{op}$	1.973	1.973	1.973	1.973	0	0
Pattern 3 : $Kw_{pp} > KW_p > KW_{op}$	0.705	0	0.986	0.986	0.282	0.282
Pattern 4 : $Kw_{pp} > KW_{op} > KW_p$	0.705	0	0.986	0.986	0.282	0.282
Pattern 5 : $Kw_{op} > KW_p > KW_{pp}$	1.973	1.973	1.973	1.973	0	0
Pattern 6 : $Kw_{op} > KW_{pp} > KW_p$	0.705	0	0.986	0.986	0.282	0.282

Notes: 1. P = peak period; PP = partial peak period; OP= off peak period.

2. Peak period demand charge = 180 baht/kw-month; energy charge = 1.22 baht/kwh for all three periods; peak period = 91.25 hours/month; partial peak period = off peak period = 319.375 hours/month.

3. Marginal benefit of a shift in energy from peak to partial peak and off peak is between marginal benefit from an energy shift from peak to partial peak and peak to off peak.

4. Energy shift into a given period resulting in an increase in demand equal to the shifted energy divided by the number of hours in this period is referred to as Case A Case B represents a simple of shift of demand from one period to another period.

Source : Calculated from Appendix A.

For a customer with load characteristics under pattern 3, 4, and 6, the marginal benefit of an energy shift from the peak period to the partial peak period is 0.705 baht/kwh for case A and zero fro case B compared with the benefit of 0.986 baht/kwh for a shift from the peak period to the off peak period for both partial peak and off peak period will result in a marginal benefit between 0.705 baht/kwh to 0.986 baht kwh the exact amount depending upon the allocation of the shift. The marginal benefit is lower at 0.282 baht/kwh for a shift from the partial peak period to the off peak period.

4.2 Net Benefit to Power Ultilities

The net benefit of a three period TOU tariff discussed in the previous section accrues to a customer in the form of consuer surplus which is realized from a customer's decision to shift his energy usage in three possible patterns i.e. from the peak period to the partial peak period; from the peak period to the off peak period; and from the partial peak period to the off peak period.

A customer's decision to shift his energy usage results in a net benefit to the power utilities and hence to the country in the form of savings in the power utilities' investment in the powe system. The net benefit or savings in investment may be illustrated below for the three patterns of energy shift between the three periods.

Let MCE_i = marginal energy cost during the ith period, I = 0, pp, op

MCC_i = marginal cpacity cost during hte ith period, I = p, pp, op

B = benefit or saivngs from power investment requrement

MB = marginal benefit

(a) Energy Shfit from Peak Period to Partial Peak Period

Savings in the pwoer system investment from an infinitesimal shift of Δ kwh from the peak period to the partial peak period may be expressed as

Case A: $B = MCE_p\Delta - MCE_{pp}\Delta + MCC_p\Delta/t_p - MCC_{pp}\Delta/t_{pp}$

Dividing through by Δ and taking limits

$MB = MCE_p\Delta - MCE_{pp}\Delta + MCC_p\Delta/t_p - MCC_{pp}\Delta/t_{pp}$

Case B: $B = MCE_p\Delta - MCE_{pp}\Delta + MCC_p\Delta/t_p - MCC_{pp}\Delta/t_p$

$MB = MCE_p - MCE_{pp} + (MCC_p - MCC_{pp}))/t_p$

(b) Energy Shift from Peak Period to Off Peak Period

Case A and B: $B = MCE_p\Delta - MCE_{op}\Delta + MCC_p\Delta/t_p$

$MB = MCE_p - MCE_{op} + MCC_p/t_p$

(c) Energy Shift from Partial Peak Period to Off Peak Period

Case A and B: $B = MCE_{pp}\Delta - MC_{op}\Delta + MCC_{pp}\Delta/t_{pp}$

$MB = MCE_{pp}\Delta\, MC_{op} + MCC_{pp}/t_{pp}$

There is no marginal capacity cost during the off peak period in the above analtsis since there is an excess capacity in the power sytem during this period. There is, however, a marginal capacity cost during the partial peak period to reflect MEA's peak demand during this period (Figure 2). The marginal capacity costs of MEA and PEA which include the capacity cost of EGAT are presented in Table 6 and are used to calculated the net benefit to MEA and PEA. Since the marginal energy cost are the same for the three periods there are no savings in energy costs and the net benefit reflects only savings in capacity investment. the net benefits to MEA and PEA are presented in Table 7.

For an energy shift from the peak period to the off peak period, the net benefit to MEA is lower than the corresponding benefit to PEA because of the former's lower marginal capacity cost which results in lower savings. The net benefit differential between the two power authorities is more pronounced for an energy shfit from the peak period to the partial peak period since MEA has to invest in its distributio system to satisfy the marginal demand increase during the partial peak period. On the other hand, there is no net benefit to PEA from an energy shift from the partial peak period to the off peak period since there is an excess capacity during the partial peak period. There is, however, some net benefit to MEA under this pattern of energy shift due to savings in its distribution investment during the partial peak period.

4.3 Total Net Benefit

The total net benefit of the TOU tariff to the country is the savings in the power utilities' investment in the power system. The benefit to a customer does not translate into the country's net benefit since it is simply a transfer payment which equals an equivalent reduction in the pwoer utilities' revenue.

The net benefit to the country must be weighed against the costs of TOU aministration and metering. It is likely that the increase in the administration costs of issuing and processing the electricity bills under the TOU tariff over the other tariff structure are insignificant since the billing

Table 6 Marginal Capacity Costs of MEA and PEA by Voltage Levels and Periods, 1990-2001

(Baht/kw-month)

Voltage Level	MCC_p		MCC_{pp}	
	PEA	MEA	PEA	MEA
Transmission	372	298	0	27
Primary	428	321	0	69
Secondary	499	327	0	83

MCC_p = marginal capacity cost during peak period

MCC_{pp} = marginal cpacity cost duirng partial peak

Source : Appendix B.

process in Thailand is computerized an there are no anticipated changes in the number of bill issances.

The TOU meter capable of recording a customer's energy and demand consumption by periods is usually more expensive than a conventional meter used in recording energy and demand consumption under the two parts tariff scheme. Since the TOU meters were used to replace the conventional meters for the large manufacturing and mining customers in 1990, the cost of the conventional meters must be considered as savings to the TOU tariff scheme. Hence, the cost difference between the TOU meter and the conventional meter is the relevant meter cost for the 1990 TOU tariff scheme.

Table 7 Marginal Benefit to Power Utilities from Energy Shift by Voltage Levels

Enery Shift from Peak Period to Partial Peak Period

	PEA		MEA	
	Case A	Case B	Case A	Case B
Transmission	4.0767	4.0767	3.1812	2.9699
Primary	4.6904	4.6904	3.2031	2.6630
Secondary	5.4685	5.4685	3.2337	2.6740

Enery Shift from Peak Period to Off Peak Period

	PEA		MEA	
	Case A	Case B	Case A	Case B
Transmission	4.0767	4.0767	3.2658	3.2658
Primary	4.6904	4.6904	3.4192	3.4192
Secondary	5.4685	5.4685	3.5836	3.5836

Enery Shift from Partial Peak to Off Peak Period

	PEA		MEA	
	Case A	Case B	Case A	Case B
Transmission	0	0	0.0845	0.0845
Primary	0	0	0.2160	0.2160
Secondary	0	0	0.2599	0.2599

Source : Table 6.

Table 8 Minimum Energy Shit Required for TOU tariff Implementation

(kwh/month)

Energy Shift from Peak Period to Partial Peak Period

	PEA	MEA
Transmission	410	563
Primary	356	627
Secondary	306	624

Energy Shift from Peak Period to Off Peak Period

	PEA	MEA
Transmission	410	511
Primary	356	488
Secondary	306	466

Energy Shift from Partial Peak to Off Peak Period

	PEA	MEA
Transmission	-	19,760
Primary	-	7,731
Secondary	-	6,425

Notes 1. Incremental meter cost = 80,000 baht

2. Opportunity cost = 8 percent

3. Meter life = 5 years

Source : Table 7.

Let the cost difference between the two types of meters equal 80,000 baht. Assuming a meter life of five years, the annuitized meter cost at 8 percent opportunity cost is 20,036.52 baht or 1,669.71 baht per month. From the marginal net benefit to the country in Table 7 the minimum amount of energy or the 'breakeven' kwh required to justify the implementation of the TOU tariff may be estimated for each of the three patterns of energy shift (Table 8). It is seen that the breakeven kwh ranges from 306 kwh per month for PEA's secondary level usage to 19,760 kwh per month for MEA's transmission level usage.

When the maximum breakeven energy of 627 kwh required for an energy shift from the peak period to the partial peak period or the off peak period is compared to the average monthly energy consumption per customer in Table 9 it is seen that the TOU tarift may be justified for all large general service customers and for medium general service customers at the primary voltage. A shift of only 0.04 percent of an average large general service customer's monthly energy consumption from the peak period to the partial peak period is required to justify the TOU tariff and the shift is required to increase to 1.08 % for an average medium general service customer at the primary voltage.

Table 9 Proportion of Breakeven KWH in Monthly Consumption Per Customer

Categories	MEA KWH/ customer	MEA Proportion of Breakeven KWH* (%)	PEA KWH/ Customer	PEA Proportion of Breakeven KWH* (%)
Residential	337	186.05	68	922.06
Small Business	997	62.89	529	99.68
Medium General Service				
Primary	177,575	0.35	57,908	1.08
Secondary	25,395	2.47	15,255	4.11
Large General Service				
Transmission	4,191,856	0.02	8,155,263	0.01
Primary	1,747,428	0.04	2,209,831	0.03
Government	11.326	5.54	1,612	38.90
Pumping	N/A	-	8,460	7.41

*Estimated from a breakeven 627 KWHper month.

APPENDIX A

DERIVATION OF MARGINAL BENEFIT UNDER A THREE PERIOD TOU TARIFF

The marginal benefit of a three period TOU tariff is analyzed by considering the effect of an infinitesimal shift of energy from one period to another period on the electricity cost of a customer with a given load characteristics.

Let DC_p = demand charge during peak period

DC_{pp} = demand charge during partial peak period

DC_{op} = demand charge during off peak period

EC_p = energy charge during peak period

EC_{pp} = energy charge during partial peak period

EC_{op} = energy charge during off peak period

t_p = number of hours in partial peak period

t_{pp} = number of hours in partial peak period

t_{op} = number of hours in off peak period

KW_i = kilowatt demand during the i^{th} period, i = p, pp, and op

KWH_i = kilowatthour consumption during the i^{th} period, i = p, pp and op

C = electricity cost

MB = marginal benefit

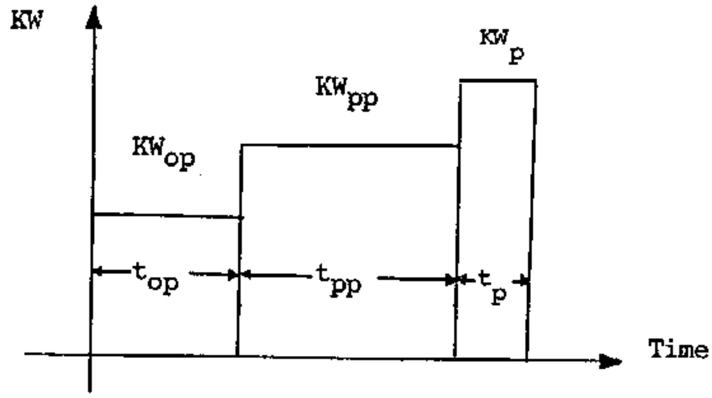
and $DC_p \geq DC_{pp} \geq DC_{op}$

$EC_p \geq EC_{pp} \geq EC_{op}$

Total $KWH = KWH_p + KWH_{pp} + KWH_{op}$

The marginal benefit of an infinitesimal shift of Δ kwh may be derived for a customer with the following loadcharacteristics

I. Load Pattern 1 : $KW_p > KW_{pp} > KW_{op}$



The electricity cost to a customer under load pattern 1 is

$$C = EC_pKWH_p + EC_{pp}KWH_{pp} + EC_{op}KWH_{op} + DC_pKW_p$$

Consider the effect of an infinatesimal shift of Δ KWH between periods on the electricity cost under the following scenarios.

a) Energy shift from peak period to partial peak period

CASE A and CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}\ KWH_{op}$$
$$+ DC_p\ (KW_p - \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p$$

$$MB = EC_p - EC_{pp} + DC_p/t_p$$

b) Energy shift from peak period to off peak period

CASE A and CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta) + DC_p(KW_p - \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p$$

$$MB = EC_p - EC_{op} + DC_p/t_p$$

c) Energy shift from partial peak period to off peak period

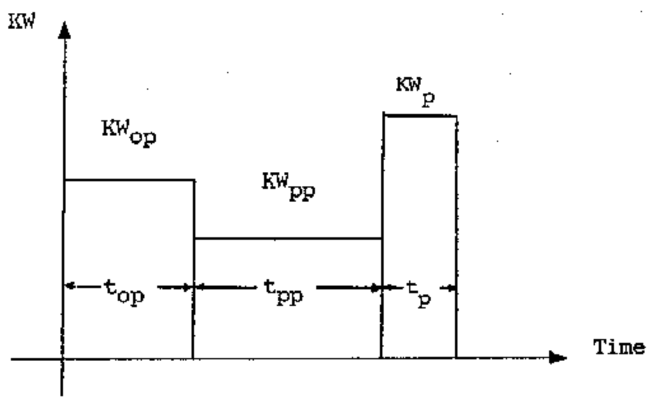
CASE A and CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta) + DC_pKW_p$$

$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta$$

$$MB = EC_{pp} - EC_{op}$$

II. Load Pattern 2 : $KW_p > KW_{op} > KW_{pp}$



$$C = EC_pKWH_p + EC_{pp}KWH_{pp} + EC_{op}KWH_{op} + DC_pKW_p$$

a) Energy shift from peak period to partial peak period

CASE A and CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}KWH_{op} + DC_p(KW_p - \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p$$

$$MB = EC_p - EC_{pp} + DC_p/t_p$$

b) Energy Shift from peak period to off peak period

CASE A and CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta) + DC_p(KW_p - \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p$$

$$MB = EC_p - EC_{pp} + DC_p/t_p$$

c) Energy shift from partial peak period to off peak period

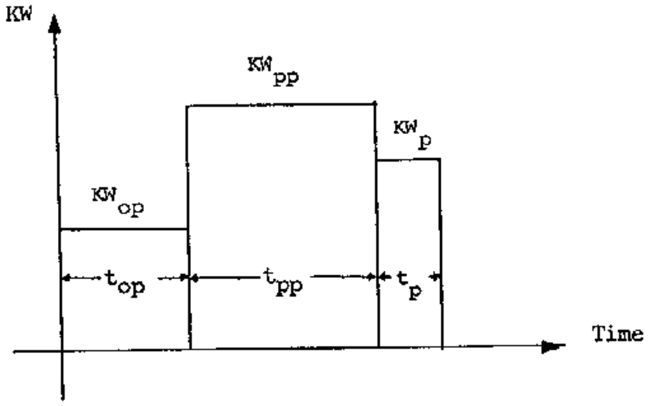
CASE A and CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta) + DC_pKW_p$$

$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta$$

$$MB = EC_{pp} - EC_{op}$$

III. Load Pattern 3 : $KW_{pp} > KW_p > KW_{op}$



$$C = EC_p KWH_p + EC_{pp} KWH_{pp} + EC_{op} KWH_{op} + DC_p KW_p + DC_{pp}(KW_{pp} - KW_p)$$

a) Energy shift from peak period to partial peak period

CASE A

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op} KWH_{op} + DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} + \Delta/t_{pp} - KW_p + \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - Dc_{pp}(\Delta/t_{pp} + \Delta/t_p)$$

$$MB = EC_p - EC_{pp} + DC_p/t_p - DC_{pp}(1/t_{pp} + 1/t_p)$$

CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op} KWH_{op} + DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} + \Delta/t_p - KW_p + \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - 2DC_{pp}\Delta/t_p$$

$$MB = EC_p - EC_{pp} + DC_p/t_p - 2DC_{pp}/t_p$$

b) Energy shift from peak period to off peak period

CASE A and CASE B

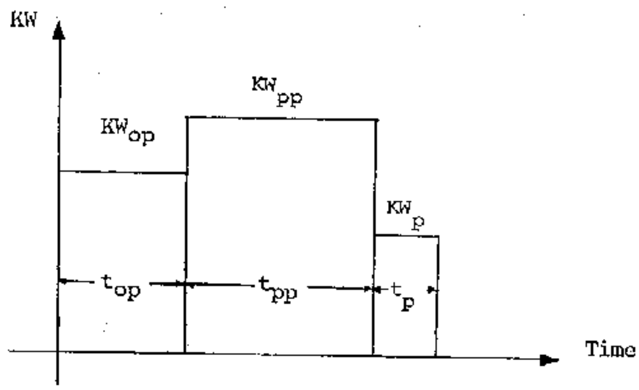
$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} - KW_p + \Delta/t_p)$$
$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p - DC_{pp}\Delta/t_p$$
$$MB = EC_p - E_{op} + DC_p/t_p - DC_{pp}/t_p$$

c) Energy shift from partial peak period to off peak period

CASE A and CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{pp}(KW_{pp} - \Delta/t_{pp} - KW_p)$$
$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta + DC_{pp}\Delta/t_{pp}$$
$$MB = EC_{pp} - EC_{op} + DC_{pp}/t_{pp}$$

IV. Load Pattern 4 : $KW_{pp} > KW_{op} > KW_p$



$$C = EC_pKWH_p + EC_{pp}KWH_{pp} + EC_{op}KWH_{op} + DC_pKW_p$$
$$+ DC_{pp}(KW_{pp} - KW_p)$$

a) Energy shift from peak period to partial peak period

CASE A

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}KWH_{op}$$
$$+ DC_p(KW_p - (\Delta/t_p)) + DC_{pp}(KW_{pp} + \Delta/t_{pp} - KW_p + \Delta/t_p)$$
$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - DC_{pp}(\Delta/t_{pp} + \Delta/t_p)$$
$$MB = EC_p - EC_{pp} + DC_p/t_p - DC_{pp}(1/t_{pp} + 1/t_p)$$

CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}KWH_{op}$$
$$+ DC_p(KW_p - (\Delta/t_p)) + DC_{pp}(KW_{pp} + \Delta/t_p - KW_p + \Delta/t_p)$$
$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - 2dc_{pp}\Delta/t_p$$
$$MB = EC_p - EC_{pp} + DC_p/t_p - 2dc_{pp}/t_p$$

b) Energy shift from peak period to off peak period

CASE A and CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} - KW_p + \Delta/t_p)$$
$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p - DC_{pp}\Delta/t_p$$
$$MB = EC_p - EC_{op} + DC_p/t_p - DC_{pp}/t_p$$

c) Energy shift from partial peak period to off peak period

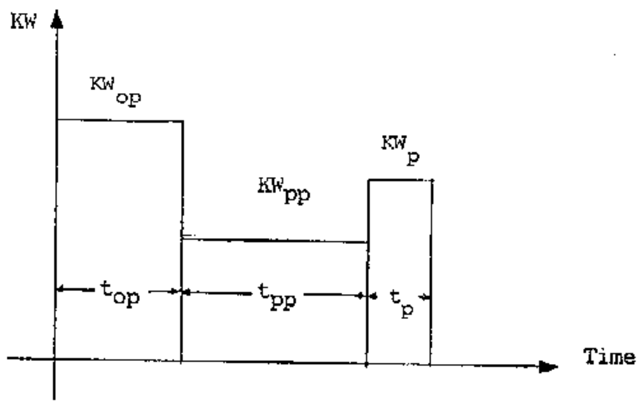
CASE A and CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{pp}(KW_{pp} - \Delta/t_{pp} - KW_p)$$

$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta + DC_{pp}\Delta/t_{pp}$$

$$MB = EC_{pp} - EC_{op} + DC_{pp}/t_{pp}$$

V. Load Pattern 5 : $KW_{op} > KW_p > KW_{pp}$



$$C = EC_pKWH_p + EC_{pp}KWH_{pp} + EC_{op}KWH_{op} + DC_pKW_p$$
$$+ DC_{op}(KW_{op} - KW_p)$$

a) Energy shift from peak period to partial peak period

CASE A and CASE B

$$C^* = EC_p(KWH - \Delta) + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}KWH_{op}$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{op}(KW_{op} - KW_p + \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - DC_{op}\Delta/t_p$$

$$MB = EC_p - EC_{pp} + DC_p/t_p - DC_{op}/t_p$$

b) Energy shift from peak period to off peak period

CASE A

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - (\Delta/t_p)) + DC_{op}(KW_{op} + \Delta/t_{op} - KW_p + \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p(\Delta/t_p) - DC_{op}(\Delta/t_{op} + \Delta/t_p)$$

$$MB = EC_p - EC_{op} + DC_p/t_p - DC_{op}1/t_{op} + 1/t_p)$$

CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{op}(KW_{op} + \Delta/t_p - KW_p + \Delta/t_p)$$

$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p - 2DC_{op}\Delta/t_p$$

$$MB = EC_p - EC_{op} + DC_p/t_p - 2DC_{pp}/t_p$$

c) Energy shift from partial peak period to off peak period

CASE A

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{op}(KW_{op} + \Delta/t_{op} - KW_p)$$

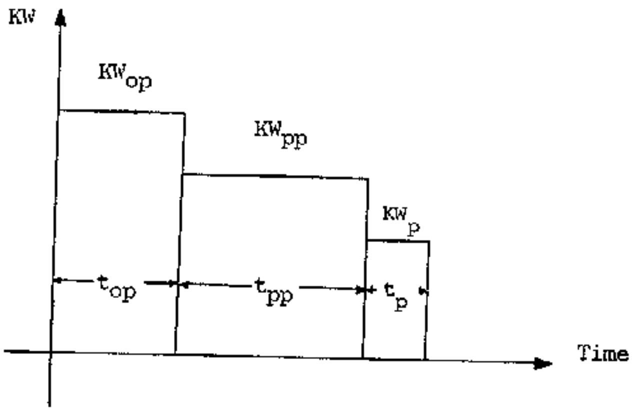
$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta - DC_{op}\Delta/t_{op}$$

$$MB = EC_{pp} - EC_{op} + DC_{op}/t_{op}$$

CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{op}(KW_{op} + \Delta/t_{pp} - KW_p)$$
$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta - DC_{op}\Delta/t_{pp}$$
$$MB = EC_{pp} - EC_{op} + DC_{op}/t_{pp}$$

VI. Load Pattern 6 : $KW_{op} > KW_{pp} > KW_p$



$$C = EC_pKWH_p + EC_{pp}KWH_{pp} + EC_{op}KWH_{op} + DC_pKW_p$$
$$+ DC_{pp}(KW_{pp} - KW_p) + DC_{op}(KW_{op} - KW_{pp})$$

a) Energy shift from peak period to partical peak period

CASE A

$$C^* = EC\ (KWH - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}KWH_{op}$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} + \Delta/t_{pp} - KW_p + \Delta/t_p)$$
$$+ DC_{op}(KW_{op} - KW_{pp} - \Delta/t_{pp})$$
$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - DC_{pp}(\Delta/t_{pp} + \Delta/t_p) + DC_{op}\Delta/t_{pp}$$

$$MB = EC_p - EC_{pp} + DC_p/t_p - DC_{pp}(1/t_{pp} + 1/t_p) + DC_{op}/t_{pp}$$

CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}(KWH_{pp} + \Delta) + EC_{op}KWH_{op}$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} + \Delta/t_p - KW_p + \Delta/t_p)$$
$$+ DC_{op}(KW_{op} - KW_{pp} - \Delta/t_p)$$
$$\Delta C = EC_p\Delta - EC_{pp}\Delta + DC_p\Delta/t_p - 2DC_{pp}\Delta/t_p + DC_{op}\Delta/t_p$$
$$MB = EC_p - EC_{pp} + DC_p/t_p - 2DC_{pp}/t_p + DC_{op}/t_p$$

b) Energy shift from peak period to off peak period

CASE A

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - \Delta/t_p + DC_{op}(KW_{pp} - KW_p + \Delta/t_p)$$
$$+ DC_{op}(KW_{op} + \Delta/t_{op} - KW_{pp})$$
$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p - DC_{pp}\Delta/t_p - DC_{op}\Delta/t_{op}$$
$$MB = EC_p - EC_{op} + DC_p/t_p - DC_{pp}/t_p - DC_{op}/t_{op}$$

CASE B

$$C^* = EC_p(KWH_p - \Delta) + EC_{pp}KWH_{pp} + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_p(KW_p - \Delta/t_p) + DC_{pp}(KW_{pp} - KW_p + \Delta/t_p)$$
$$+ DC_{op}(KW_{op} + \Delta/t_p - KW_{pp})$$
$$\Delta C = EC_p\Delta - EC_{op}\Delta + DC_p\Delta/t_p - DC_{pp}\Delta/t_p - DC_{op}\Delta/t_p$$
$$MB = EC_p - EC_{op} + DC_p/t_p - DC_{pp}/t_p - DC_{op}/t_p$$

c) Energy shift from partial peak period to off peak period

CASE A

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{pp}(KW_{pp} - \Delta/t_{pp} - KW_p)$$
$$+ DC_{op}(KW_{op} + \Delta/t_{pp} - KW_{pp} + \Delta/t_{pp})$$
$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta - DC_{pp}\Delta/t_{pp} - DC_{op}(\Delta/t_{op} + \Delta/t_{pp})$$
$$MB = EC_{pp} - EC_{op} + DC_{pp}/t_{pp} - DC_{op}(1/t_{op} + 1/t_{pp})$$

CASE B

$$C^* = EC_pKWH_p + EC_{pp}(KWH_{pp} - \Delta) + EC_{op}(KWH_{op} + \Delta)$$
$$+ DC_pKW_p + DC_{pp}(KW_{pp} - \Delta/t_{pp} - KW_p)$$
$$+ DC_{op}(KW_{op} + \Delta/t_{pp} - KW_{pp} + \Delta/t_{pp})$$
$$\Delta C = EC_{pp}\Delta - EC_{op}\Delta - DC_{pp}\Delta/t_{pp} - 2DC_{op}\Delta/t_{pp}$$
$$MB = EC_{pp} - EC_{op} + DC_{pp}/t_{pp} - 2DC_{op}/t_{pp}$$

APPENDIX B

SUMMARY OF MARGINAL CAPACITY COSTS FOR MEA AND PEA

The following summary of marginal capacity costs by periods are summarized from **Report on Marginal Cost of Electric Power**, Monenco consultants Limited in association with the National Institute of Development Administration, December, 1990. Only the demand related costs are reported below.

1. MEA Marginal Capacity Cost (baht)

Purchase from EGAT	3,495	291
Per Kw delivered by EGAT	Annual	Monthly
Transmission	318	27
Primary	459	38
Secondary	109	9
	4,381	365

Lossed including street lighting allocation as percent of inputs

Transmission	2.26
Primary	4.53
Secondary	4.56

Marginal cost per kw demand during peak period

Transmission	3,576	398
Primary	3,745	312
Secondary	3,924	328

Marginal cost per kw demand during partial peak period

Transmission	325	27
Primary	833	69
Secondary	995	83

2. PEA Marginal Capacity Cost

Marginal cost per kw demand during peak period

Transmission	4,463	372
Primary	5,138	428
Secondary	5,990	499

Marginal capacity cost during off peak period is zero.