Tutorial (01)

1). Pumped - storage power plant.

* Pumped storage power plant is a hydro powerplant which's reservoir is created by pumping water to a higher location. (Not like building a dam accross a river). Main characteristic of this is quick dispatchability.

* In demand management, when demand goes up (higher than the generation) frequency goes down. In such a case pump hydro plants can be dispatched and do frequency control.

* In addition while when off peak hours (Day time, where higher solar penetration takes place) pump hydro can be charged.

* Flywheel, diesel generators. (Rotating machines with quick dispatchability)

2). Incandecent lamp. : 35-40%. - LED lamp
Induction motor : 85 - 88%. -
oil fired boiler : 60%. -
steam generation : 50-60%. - combined cycle - 65-75%.
three-brick fire place : 3-4%. - pressure cooker - 75%.
internal combustion engine : 30-35%. - EV - 70%.

3). PF = 0.65 lagging
↳ improved to 0.98 when factory shuts down
Factory demand = 410kVA (peak)

a). lower power factor means higher kVA. for the same real power. Improved power factor means lower reactive power.

1). Lower maximum demand charges.
* This depends on the apparent power. A low power factor means higher kVA for same real power. So improved power factor means lower kVA value. which is lower charges.

2). Equipment efficiency
* High PF means less current. So ohmic losses are minimum.

3). Increased system capacity.
* Reduced reactive power means freeing more space in TL, Transformers which could be used to power more equipment.

4). Improved voltage stability.
* lower reactive power means better voltage stability
↳ How?

b). 1500 Rs/kVA

$PF_1 = 0.65$
$PF_2 = 0.98$

Active power needed by the factory $\}$ = P.

P = Apparent power x PF $A_1 = 410\,kVA$.

$P = A_1 \times 0.65 = 410 \times 0.65 = 266.5\,kW$

Once the power factor improves

$P = A_2 \times 0.98$

$266.5\,kW = A_2 \times 0.98$

$A_2 = 271.94\,kVA$

$Q = \sqrt{S^2 - P^2}$
$= [410^2 - 266.5^2]^{1/2}$
$= 311.573\,kvar$ ← total reactive power initially

$Q = \sqrt{S^2 - P^2}$
$= [(271.94)^2 - (266.5)^2]^{1/2}$
$= 54.121\,kvar$ ← new reactive power rating

Reactive power rating of the capacitor $\}$ $= 311.573 - 54.121$
$= \underline{\underline{257.452\,kvar}}$

Financial benifit $= (410 - 271.94) \times 1500$
$= \underline{\underline{207{,}090}}$/= (per month)

c). Capacitor bank : 5000 per/kvar
Switch gear and labour : 120,000

Total cost of implementing $= 5000 \times 257.452 + 120{,}000$
$= 1{,}287{,}260 + 120{,}000$
$= 1{,}407{,}260$/=

Payback Period $= \dfrac{1407260}{207090} = \underline{\underline{6.8 \text{ months}}}$.

* Yes. The investment is recommended.

time of use regimes → time of use tarrifs.

04).

Day ; 05:30 → 18:30

Peak ; 18:30 → 22:30

off peak ; 22:30 → 05:30

* list the opportunities available for this customer to effectively manage the demand.

* chiller demands high when 10:00 to 16:00. during day. we can pre cool the building or use pre cooled water storage during off peak. which reduces the energy usage during day and peak hours.

* During peak hours, total demand rises 400kW. If we could reschedule the some of work to off peak, or use a demand response battery or something like that we could lower maximum demand charges.

* Base load is somewhat like 200-250kW even when low occupancy times. If we could do an energy audit for HVAC, lighting and other equipment we might find a way to reduce the base loads as well

ii). Air conditioning → 100kW (08:30 - 17:30)

2 x 250kVA transformers

* New modification would exceed the substation capacity.

$P = S \times PF$

$450kW = 500kVA \cdot PF$

$PF = 0.9$

* Assuming average demand of 350kW during office hours. (Before the office wing addition)

* with the current assumptions current power factor is 0.9 otherwise substation would be overloaded.

* when we selecting the air condition and lighting we should more consider about the var ratings of the equipment

Maximum Q value could be 217.95kvar.

$$Q = \sqrt{S^2 - P^2}$$
$$= \left[500^2 - (450)^2\right]^{1/2}$$
$$= 217.95\,kvar$$

* Reactive power from all the equipment should be lesser than 217.95kvar.

5). Demand side management is the planning, implementation and monitoring of activities design to encourage consumers to modify their energy consumption patterns.

↳ objectives

1). Reduce peak demand.

2). Improve energy efficiency

3). Shift load

4). Improve grid stability

5). Reduced carbon footprint

Tutorial (2)

Buying from or selling to 3^{rd} party.

Q1). a). Generation, Transmission, Distribution, Supply

b). Capacity cost payable to transmission utility. = \$15 per kW per month.

Maximum demand = 300MW

Energy sold = 1500GWh/year.

Cost → capacity, energy.

capacity * infrastructure

energy * fuel

(i). 250 million

depreciation = 250 × 0·05 = 12·5 million

Regulatory return = 0·02 × 250 = 5 million

Interest payable = 3

O&M costs = 20

Regulatory return = 5

Depreciation = 12.5

40·5 million

cost for distribution company per year

capacity cost = $15 \times 300 \times 10^3 \times 12$

= 54 million

amount that distribution utility should pay to transmission utility even the revenue was null

Total amount of that could charged from customers $\}$ = 40·5 + 54

= 94·5 million

(ii) tarrif methods. ?

Flat tariff ⟶ $\dfrac{94.5 \times 10^6 \text{ USD/year}}{1500 \times 10^6 \text{ kWh/year.}} = \underline{\underline{0.063 \text{ USD/kWh}}}$

(iv). * usually electricity charge comes up with apparent power. In above case reactive power neglected.

(v). Distribution utility energy (1500GWh)

(750GWh) 50%. House hold.

→ Annual load factor = 30%.

→ contribution factor = 90%.

50% (750GWh) commertial users

→ Annual load factor = 40%.

load factor = $\dfrac{\text{Average power gen}}{\text{Maximum demand}}$

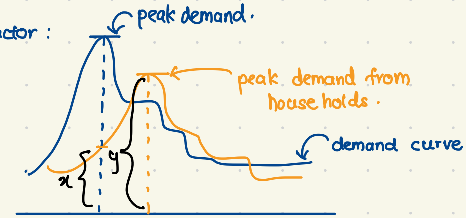
capacity factor = $\dfrac{\text{Actual power output}}{\text{Maximum demand.}}$

Maximum demand of

House hold = $\dfrac{750 \times 10^3}{0{\cdot}3 \times 8760}$ = 285·39 MW

commertial = $\dfrac{750 \times 10^3}{0{\cdot}4 \times 8760}$ = 214·041 MW.

contribution factor :



* For the contribution factor we should x and y

* How much of a certain supply or demand contribute for the peak.

* contribution factor is the amount of contribution to its own peak

Household contribution $= 285.39 \times 0.9$
$= 256.851$

Commertial contribution $= 300 - 256.851$
$= 43.15$

contribution factor $= \frac{43.15}{214.041} = \underline{\underline{20.16\ \%}}$

capital cost HH $= \frac{94.5 \times 10^6 \text{ USD}}{750 \times 10^6 \text{ kwh}} \times \frac{256.851}{300}$

$= \underline{\underline{0.1075 \text{ USD/kwh}}}$

capital cost Commecial $= \frac{94.5 \times 10^6 \text{ USD}}{750 \times 10^6 \text{ kwh}} \times \left(\frac{43.15}{300}\right)$

$= \underline{\underline{0.018 \text{ USD/kwh}}}$

2022 - Energy systems.

Question (01)

a). 1). Higher dependancy on hydro. In dry season we are fucked.
2). Rising coal prices. which causes higher prices.
3). Financial instability of CEB.

b). Coal → 300\$ / tonne
LNG → 40\$ / MMBTU

1.419×10^{10} kg

Global supply chain disruptions.
* covid-19 and Ukraine-Russian war disrupted mining, infrustructure causes rise in price

Surge in energy demand post pandemic
* Rapid economic recovery and industrial development activities in asia.

c). 2011 - 2020 → 37469.4 GWh → 38%. 25,000 kJ/kg
\$80 per ton

CC power p. → \$80 per bbl.
→ 48% , 42,000 kJ/kg

$1 m^3 \rightarrow 1000 \ell$
$1 \ell \rightarrow 10^{-3} m^3$

Assuming the amount of coal needed x

$$10^9 \times 37469.4 \text{ GWh} \times 3600 = x \times 25{,}000 \times 10^3 \text{ J} \times 0.38$$

$$x = \frac{37469.4 \times 10^9 \text{ J/s} \cdot 3600 \text{s}}{25{,}000 \times 10^3 \times 0.38} = 1.42 \times 10^{10} \text{ kg}$$

7.871×10^6

Amount of diesel needed y.

159 l

$$10^9 \times 37469.4 \times 3600 = y \times 42{,}000 \times 10^3 \times 0.48$$

$$y = 6.69 \times 10^9 \text{ kg}$$

Coal cost $= 1.42 \times 10^6$ ~~tonne~~ $\times$ \$80 / ~~tonne~~
= 113,600,000 \$
= 113.6 million USD

Diesel cost $= \dfrac{6.69 \times 10^9 \text{ kg}}{850 \text{ kg/m}^3 \times 0.159} \times \$80 / \text{bbl}$

= 3960.044 million USD

National saving = 3960.044 - 113.6
= 3846.44 million USD

Question (2)

a). Integrated approach : energy sector planning method refers to comprehensive coordinated method considering all aspects of energy system. (supply, demand, infrustructure economics).

* Efficient resource allocation
* Improved energy security
* Environmental sustainability.

b). * Government should provide subsides for the vulnerable groups which are contributing a considerable amount to national economy

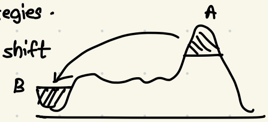
* The long term generation plan for the power plants should be proceed as sheduled
* Expanding the Renewable energy to ensure long term cost stability.
* Adjust local fuel and electricity prices to reflect the true cost gradually, avoiding sudden shocks. Meanwhile it should be ensured energy pricing strategy won't increase the production costs excessively, allowing SL goods and services to remain competitive internationally

c). Disadvantages of low offpeak demand.

* Base load power plants should run any ways, But when the demand is low the renewable energy harvesting is low.
* Frequency imbalances, which case lower power quality.
* Grid instability.

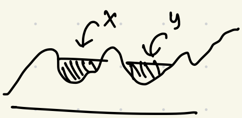
Mitigation strategies.

* load shift



* shifting load A peak to the off peak @ B.

* valley filling



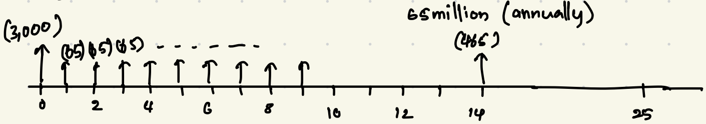
* filling the demand valleys from the peak demand.

* Introducing time of use tariffs
* Energy

Question (3)

10 MW ground mounted solar form $\rightarrow$ 3,000 Millon (upfront) 0.18 PF

65 million (annually) 33.50 Rs/kWh



a). Annual energy output $= 10\times10^3\ kW \times 8760h \times 0.18$

$= 8.760\times10^7\ kWh \times 0.18$

$= 1.577\times 10\ GWh$

$= \underline{15.77 GWh}$

Annuity factor $\rightarrow \frac{1}{0.12}\left[1 + \frac{1}{(1.12)^{25}}\right]$

b). Total cost $= 3000 + \frac{65}{0.12}\left[1 - \frac{1}{(1+0.12)^{25}}\right] + \frac{400}{(1+0.12)^{14}}$ $= 3591.7$ million

levelized cost $= \frac{3591.7\times\cancel{10^6}\ Rs}{15.77\times\cancel{10^6}\ kWh \times 7.843}$

$= \underline{29.04\ Rs/kWh}$

c). $BCR = 1.3 = \frac{X}{29.04}$

$X = 37.752\ Rs/kWh$

Question (04)

a). Energy intensity = 25%.
Production cost = 30 million.

$$\text{Energy intensity} = \frac{\text{Electricity cost}}{\text{Total production cost}} \times 100\%$$

cost of electicity $= 0.25 \times 30$ mill
$= 7.5$ million

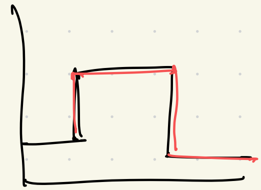
production cost = 30 million − 7.5 million
= 22.5 million

b). Generators − 2hours − peak
peak demand ⟶ 800kW

Amount of power from generators $= 200\text{ kW} \times 2h$
$= 400\text{ kWh}$

Amount of diesel $= \dfrac{400\text{ kWh}}{4\text{kwh}/l} = 100 l$

Diesel cost $= 430 \times 100$
$= 43{,}000$ LKR



Reactive power cost

Diesel cost per month $\} = 43{,}000 \times 30$
$= 1.29$ million LKR

$$\text{Electricity cost} = \left[(500 \times 7) \times 15 + (800 \times 13) \times 29 + (200 \times 2)^{\times 34.5} + \frac{200}{0.94} \times 1500 \right] \times 30 + 1.29 \text{ million LKR} + 4000$$

= 21 millions. LKR

$$\text{Energy intensity} = \frac{21 \text{ million}}{(22.5+21) \text{ million}} \times 100\%$$

$= 48.3\%$

2020 - Energy systems.

Question (01)

a). * Gulf war
* Ukraine - Russian war.
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