B.TECH DEGREE EXAMINATION JANUARY 2023

Seventh semester

Electrical & Electronics Engineering

Power System Restructuring and Deregulation

Answer key

PART A ---- (10*2=20 MARKS)

1. **Define market power**
   Market power refers to a company's relative ability to manipulate the price of an item in the marketplace by manipulating the level of supply, demand or both.
2. **List any 4 principles of ISO (IT--2)**
   Loss compensation, capacity reserves, frequency regulation, congestion management and voltage support.
3. **What is price area congestion management? (IT--2)**
   This method consists of splitting a power exchange into geographical bid areas with limited capacities of exchange. When congestion is predicted, the system operator declares that the system is split into areas at predicted congestion bottlenecks.
4. **Define TTC(IT--2)**
   TOTAL TRANSFER CAPABILITY
   The amount of electric power that can be transferred over the interconnected transmission network in a reliable manner while meeting all of a specific set of defined pre and post contigency system conditions.
5. **What are the different components of LMP**

- system energy price
- Cost of marginal losses
- Congestion cost

6. Define LMP
   LMP stands for **Locational Marginal Pricing** and represents the cost to buy and sell power at different locations within wholesale electricity markets, usually called Independent System Operators (ISOs).
7. **What are the various transmission pricing methods?**

- Rolled-in (embedded) transmission pricing
- Marginal transmission Pricing
- Composite transmission pricing

8. **What is postage stamp method?(model exam)**
   Postage stamp methodology is the simplest and easy to implement methodology of transmission pricing. A postage stamp rate is a fixed charge per unit of power transmitted within a particular zone. The rate does not take into account the distance involved in the wheeling. There are various versions of postage stamp methodology. In some versions, both, generators and loads are charged for transmission usage, while in others, only loads pay for the same

9. What are advantages of ABT?

- Commercial and operational disputes resolved. Faster settlement process.
- Transparency and sharing of the information to all participants-improved trust.
- Voltages improved, Transmission losses reduced, Transmission capacity increased.
- Help to enforce grid discipline by maintaining frequency in prescribed band (49.5-50.5Hz) and control frequency excursions. And equipment damage

10. What is Indian Energy Exchange?

The Indian Energy Exchange or IEX is an electronic power trading marketplace for electricity corporations and boards to trade contracts related to energy.

PART B

11. Explain market model and compare the various market models?IT-1 (11 marks)

- Multilateral transaction model
- Mandatory system operator model
- Voluntary system operator model

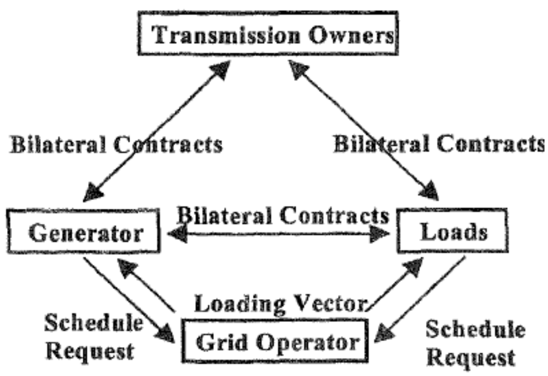
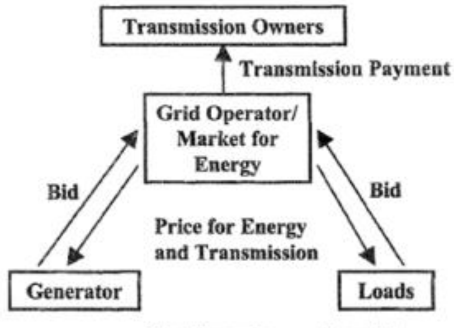


Figure Multilateral transaction model

- The multilateral transaction model is based on bilateral tranasction among market participants.
- For example, the proposed structure of the MIDwest USO is closely related to the multilaterla transnaction model.
- The model consists of thee stages in completing tranactions. Firstly, individual buyers and sellers make bilateral trades with one another without disclosing the price and propose the agreed trades to the TP for physical Implementation.
- The TP, upon receiving the proposed transactions, makes decisions whether or not to allow the transactions based on an analyis of transmission network constraint.



Mandatory system operator model

- The mandatory system operator model is developed based on the existing practices of tight power pools.
- The structure of the PJM ISO resembles the mandatory system operator model.
- In this model the TP becomes the sole centralized market maker for overseeing economically and functionally bundled energy and transmission trades.
- The spot market refers to a place where this type of centralized market-based trades takes place. Shows the relation among market participants

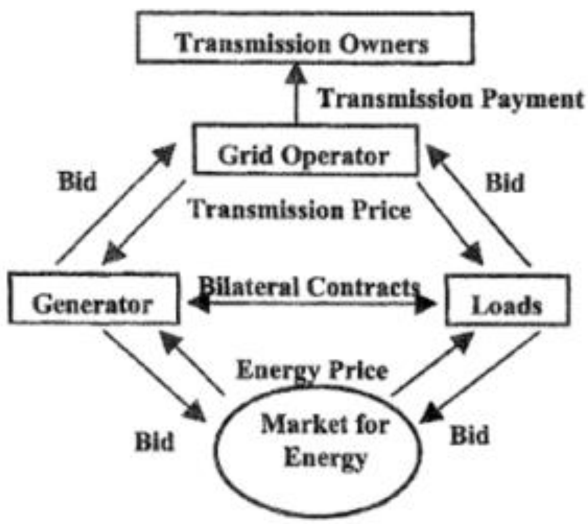


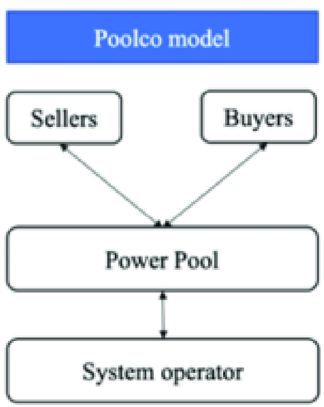
Figure Voluntary system operator model

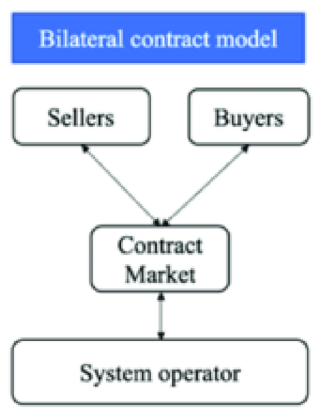
- In this model both bilateral and centralized market-based trades are allowed.
- The presence of spot market transactions is desired because of the requirement for continual balance of instantaneous supply with uncertain demand, particular to the electricity industry, while direct access and customer choice are achieved via bilateral trades.
- The level of efficiency can be compared are each of the above three market structures by studying the operation and planning of the system under each structure

12. Enumerate Poolco restructuring model (11 marks)

POOL MARKET---8 marks

•An electricity pool facilitates competition between generators and the calculation of the price paid for electricity by buyers.
•All the market participants– generators, system operator, market operator, suppliers, etc., are signatories to a pooling agreement that guide the operations of the pool
• A pool can be a compulsory pool or a voluntary pool.
• A compulsory or gross pool requires all generators, except the smallest ones, to sell their output to the pool at the pool's price.
•In a voluntary or net pool, generators can agree bilateral trades with buyers for the delivery of electricity, but must inform the system operator who takes it into account when scheduling
•Electricity pools require generators to submit bids indicating how much electricity they can generate at a given price.
•The generators can bid at any price they like (price-based pools) or the bid price could be based on predetermined variable costs (cost-based pools)



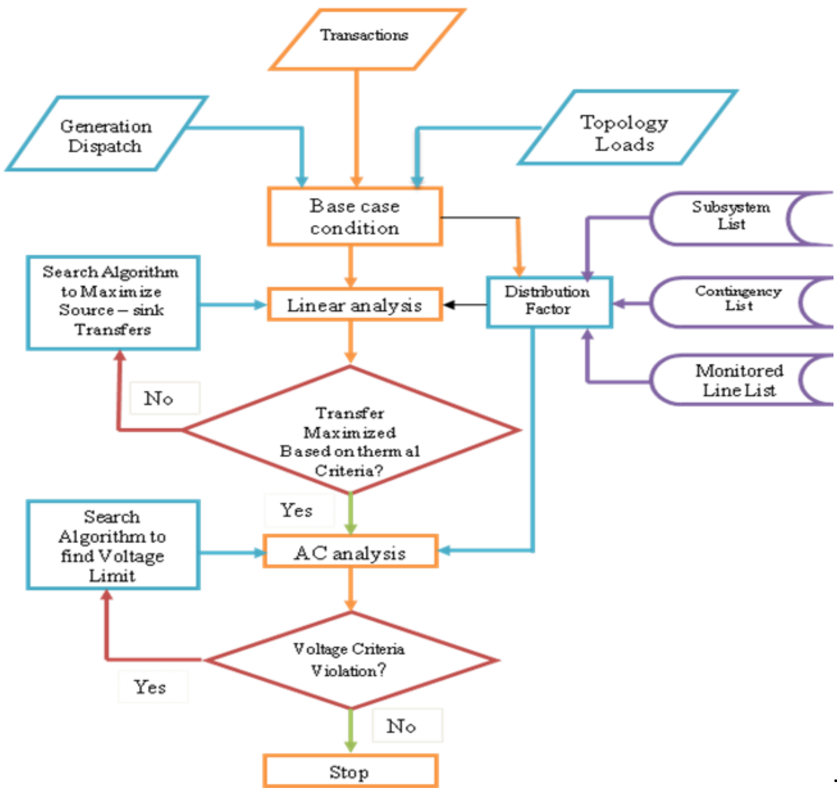


3 marks

13. Describe the method of calculating ATC (11 marks)---IT-1,model exam

- A broad way of classifying methods is based on the type of limit considered, i.e., Thermal limit, Voltage limit or the Angular stability limit.
- The DC power flow methods take into consideration only the thermal limits.
- The AC Optimal power flow (OPF) methods consider thermal as well as voltage limits. Then, there is another version called Continuation power flow method (CPF).
- It considers a series of power system solutions to be solved and tested for limits.
- The amount of transfer is gradually increased from the base case until a binding limit is encountered. A method based on continuation power flow, incorporating limits of reactive power flows, voltage limits, as well as voltage collapse and line flow limits. DC **power transfer distribution factors** (PTDF) utilizes DC load

flow based formulation, and computation of simultaneous ATC has also been considered using an optimization based approach.



---4 MARKS

It considers a series of power system solutions to be solved and tested for limits.

ATC Calculation using PTDF and LODF based on DC Model---4 MARKS

- One way of calculating ATC from node A to node B is to use DC load flow repetitively by increasing the amount of transaction until a limit of any of the corridor is reached. However, this is computationally inefficient.
- Instead, the Power Transfer Distribution Factor (PTDF) can be used to calculate the maximum allowable flow for a given pair of injection and take-off points. It is also necessary to consider the effects of contingencies like line outages.
- This can be achieved using Line Outage Distribution Factor (LODF). Let us first see the details of DC load flow model.

DC Load Flow Model

Following are the assumptions when DC model is employed instead of AC model:

- Voltage magnitudes are constant.
- Only angles of complex bus voltages vary.
- The variation in angle is small.
- Transmission lines are lossless.

These assumptions create a model that is a reasonable first approximation for the real power system, which is only slightly nonlinear in normal steady state operation. The model has advantages for speed of computation, and also has some useful properties like linearity and superposition.

With these assumptions, power flows over transmission lines connecting bus i and bus j is given as:

$$P_{lm} = \frac{1}{x_{lm}}\left(\theta_l - \theta_m\right) \quad ....(1)$$

Where,

x_{lm} line inductive reactance in per unit

θ_l phase angle at bus l

θ_m phase angle at bus m

The total power flowing into the bus i, Pi, is the algebraic sum of generation and load at the bus and is called a bus power injection. Thus,

$$P_i = \sum_j P_{ij} = \sum_j \frac{1}{x_{ij}}\left(\theta_i - \theta_j\right) \quad ....(2)$$

This can be expressed in a matrix form as:

$$\begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix} = \left[B_X\right]\begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix} \quad ....(3)$$

Where, the elements of the susceptance matrix BX are functions of line reactances . One node is assigned as a reference node by making its angle zero and deleting corresponding row and column in $\left[B_X\right]$ matrix. Thus,

$$\left[X_{init}\right] = \left[B_{X,reduced}\right]^{-1}$$ ......(4)

The dimension $\left[X_{init}\right]$ of obtained is $(n - 1 \times n - 1)$. Let us augment it by adding zero column and row corresponding to reference bus. The angles in equation.3 can be found out as

$$\begin{bmatrix} \theta_1 \\ M \\ \theta_n \end{bmatrix} = [X] \begin{bmatrix} P_1 \\ M \\ P_n \end{bmatrix}$$ ....(5)

Thus, power flow over line lm can be found out using equation 1.

Power Transfer Distribution Factor (PTDF)----3 MARKS

- From the power transfer point of view, a transaction is a specific amount of power that is injected into the system at one bus by a generator and drawn at another bus by a load.
- The coefficient of linear relationship between the amount of a transaction and flow on a line is represented by PTDF.
- It is also called sensitivity because it relates the amount of one change - transaction amount - to another change - line power flow.

PTDF is the fraction of amount of a transaction from one bus to another that flows over a transmission line. $PTDF_{lm,ij}$ is the fraction of a transaction from bus i to bus j that flows over a transmission line connecting buses l and m.

$$PTDF_{lm,ij} = \frac{\Delta P_{lm}}{P_{ij}}$$ ....(6)

14 Discuss in detail about different role of transmission planning and transmission capability (11 marks) ---- IT2

Explanation------8 marks

- The electric transmission system is one of the most complex man –made systems.
- Due to the externality stemming from the operation of transmission system implementing market mechanism to the industry requires a fair level of understanding of not only economic, financial and regulatory aspects but also engineering consequences of restructuring.
- In the dependent phase the TP functions as a part of vertically integrated utility. In the passive phase the TP stands alone and oversees overall market activities.
- The market participants are required to submit their intended use of the system to the TP and based on the formation the TP allocates transmission capacities following the strict rules set by regulators.
- The TP assumes no financial responsibilities and has minimal interactions with market participants.
- As shown in figure 1 there are three different structures of TP under this phase.
    - In the active phase the TP participates in every phase of market activities. The functions by TP under this phase can be categorized into two: of market maker and of service provider.

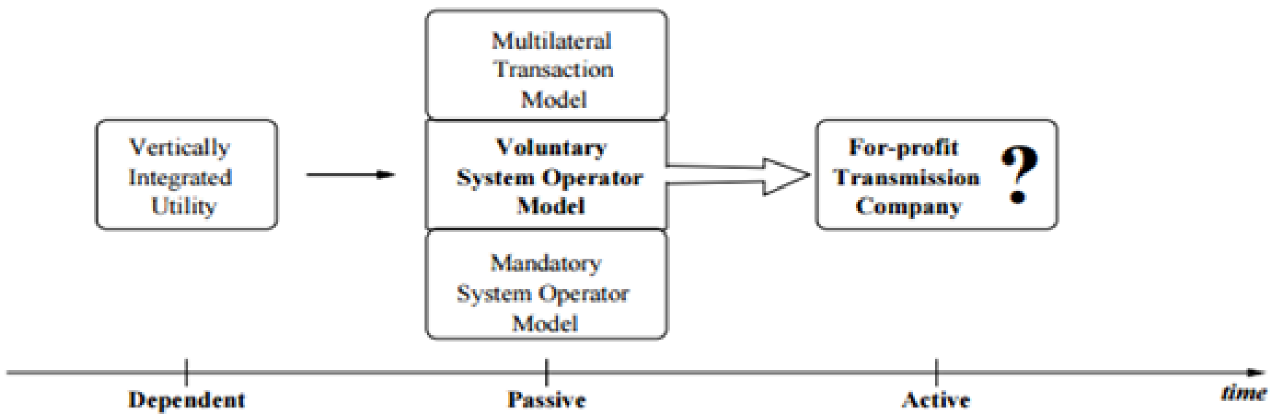


Figure 1: Role of Transmission Provider-----3 marks

Of these two only the function of market maker is under strict regulation. As a service provider the TP assumes full financial liability but is under no regulation.

The operation and planning of the system by TP, therefore, can be viewed as a combined optimization problem of short – term generation scheduling and investment in new generation and transmission to balance load demand deviations ranging from hourly through seasonal and long–term and to do this at the lowest cost. A possible mathematical formulation of this problem is given as:

$$\min_{I_l^T, I_{i,g}^G, P_{i,g}} \varepsilon \left\{ \sum_i \int_{t_0}^{T} e^{-pt} \left(c_{i,a}\left(t, P_{i,a}(t)\right) + C_{i,a}^G(K_i^G(t), I_{i,a}^G(t), t)\right) dt + \sum_l \int_{t_0}^{T} e^{-pt} \left(C_l^T(K_l^T(t), I_l^T(t), t)\right) dt \right\}$$

Subjected to:

$$\frac{dK_i^G}{dt} = I_{i,a}^G(t); \quad K_i^G(t_o) = K_{i,to}^G$$
$$\frac{dK_l^T}{dt} = I_l^T(t); \quad K_l^T(t_o) = K_{l,to}^G$$
$$I_{i,a}^G(t) \leq 0, \ \ I_l^T \leq 0$$
$$F_i\left(P_g(t), P_L\right) \leq \ F_i^{max}(K_t): \mu_i(t)$$
$$P_{i,a}(t) \leq \ K_i^G \qquad : \ \eta_i(t)$$
$$\sum_{i=1}^{n} P_{i,a}(t) = \sum_{j=1}^{n_a} P_{L,j}(t) \qquad : \ \lambda(t)$$

where

K_i^G: the amount of installed generation capcity at node i

K_i^T: the amount of installed transmission capacity for line l

$I_{i,a}^G$: the rate of investement in generation capacity using technology a at node i

I_l^T : the rate of investment in transmission capacity fo line l

$C_{i,a}^G(K_i^G(t), I_{i,a}^G(t), t)$: the cost of investment using technology a at node i

$C_l^T(K_l^T(t), I_l^T(t), t)$: the cost of investment in line l

$P_{i,a}(t)$: the production using technology a at node i, at time t:

$Pg(t) = [P_{1,a1}(t), \ldots\ldots\ldots\ldots P_{n,an}(t)]$

$C_{i,a}$: the most of generation using technology a at node i, excluding

$P_{L,j}(t)$: the uncertain (uncontrolled) load at node j, at time t:

$P_L(t) = [P_1(t), \ldots\ldots\ldots\ldots P_n(t)]$

$F_i\left(P_g(t), P_L\right)$: the flow on line l as a function of ssytem generation and demand

$F_i^{max}(K_t)$: the maximum allowable flow on line l as a fucntion of amount of installed transmission capacity: due to security constraints,

$F_t << K_t$

ρ: discount rate of risk – free investment

$\mu_i(t), \eta_i(t), \lambda(t)$: Lagrangian multipliers for corresponding constraints.

The optimization period, T in the problem is no longer of two time intervals over which the genration or transmission investements are valued.

As the system operator/planner decides the level of production and the rate of investement on generation and transmision, $P_{i,n}(t)$, $I_{i,a}{}^G$ and I_t^T serve as control variable in this formulation.

The state variables of the system are $\mu_t(t)$, $\eta_i(t)$, K_i^G and K_t^T, for the status of the system operation can be accurately appreciated by examining these variables.

- This formulation captirs many well-known trade-offs revelant for the efficiency of the power industyr: the relationship between the investement timing nad the balance of the costs and benefits over time, the value of different technologies at different locations used to prodcue power, and complementarity of genration capacity and transmission capacity .
- There are two noticable features considering the operation and planning of the system by TP (as a part of vertically integrated utility) as the combined optimization problem: the

apparent complexity of the problem and the implied assumptions of return on investement based on costs Ci,a^G, C_l^T and $C_{i,a}$.

UNIT-III

15 Classify various types of Ancillary Services and black start capability service (11 marks)---model exam

There can be various ways of classifying the above ancillary services. ----**6 marks**

One common approach would be to identify when and how frequently these services are required by the system operator. Thus, three groups can be formed:

1. Services required for routine operation:

These are the services which the system operator requires quite frequently. Some of these may be required to provide corrective action on minute-to-minute basis. Following services can be grouped under this category:

(a) System control

(b) Reactive power support

(c) Regulation

(d) Load following

(e) Energy imbalance

(f) Real power loss displacement

2. Services required to prevent an outage from becoming a catastrophe:

These services prevent the system from going out of step even if a major event occurs. These do not come into picture on daily basis, or rather; no proactive measures are required to be taken either by the system operator or the service provider on daily basis. Their effectiveness is sensed only under contingent situation. Following services fall under this category:

(a) Spinning reserve

(b)Supplemental reserve

(c)Network stability services

3. Services needed to restore a system after blackout:

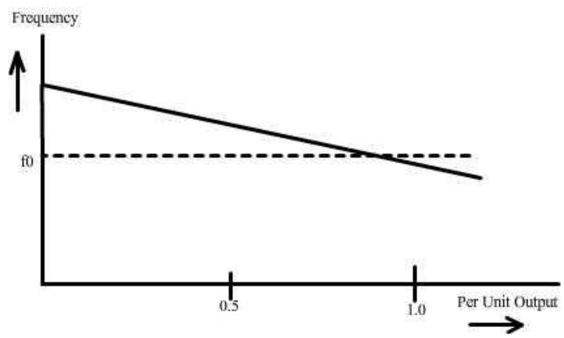
Re-energizing the system after complete blackout requires support from certain generating stations, which can pickup generation even in the absence of external electricity support. Such generating units provide the system black start capability. These services are very rarely used.

A closer look at the list of ancillary services reveals that they are either related to:

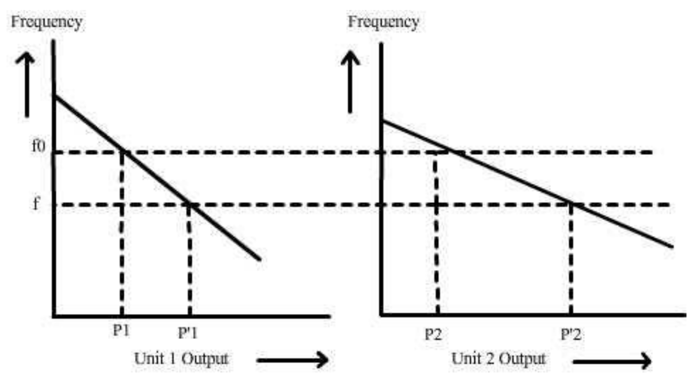
1. Generation-load balancing issues or
2. The network security related issues.

LOAD GENERATION BALANCING RELATED SERVICES

- There can be various ways of classifying the above ancillary services.
- One common approach would be to identify when and how frequently these services are required by the system operator Thus, three groups can be formed:
- Frequency deviations, if large enough, may lead to total system collapse. If the system frequency drops drastically due to a sudden mismatch of load and generation, the under-frequency protection relays isolate the generating units to avoid damage.
- This disconnection of generating units further increases the drop in frequency. This unbalance and series of incidences may cause disconnection of tie lines and affect the stability of neighboring control areas.
- The imbalance between load and generation may arise due to uncertainties in demand forecasting, generators' inability to follow up the changes in load and generation or load trips.
- The vertically integrated utility was responsible for maintaining sufficient generation to cope up with the load variations and maintain the reliability.



Generator droop characteristics



Two units sharing same load

Load Following

Load following is the use of online generation equipment to track the intra and interhour changes in customer loads. Unlike the minute-to-minute fluctuations, which are generally uncorrelated among customers, the long-term changes in customer loads are generally correlated with each other.

Spinning Reserve Services

Unlike the regulation and load following services, the reserve services are designed to be activated during large power deficits under a contingent situation. Depending upon the minimum time in which the generation should start providing corrective action, the ancillary services are classified into following two categories:

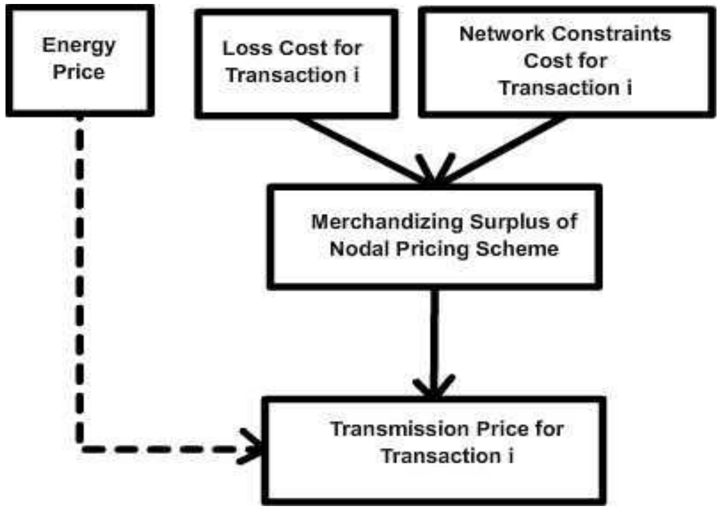
- Spinning reserve services
- Supplemental reserve services

BLACK START CAPABILITY SERVICE------5 marks

- A blackout is a rare contingency, but it nevertheless does occur.
- In order to reduce the economical and social consequences, it is important to restore power as fast as possible.
- The system operator is then bestowed with the responsibility of restoring the system to normal operating state as soon as possible.
- However, restoration of the system after a major blackout is not an arbitrary process, but needs a methodic sequential approach.
- Restarting of large thermal power plants requires major chunk of electric power for its auxiliaries.
- On the other hand, the electric power resources like hydro plants, diesel generators, etc., can be started without help from the grid. The system operator is required to have enough of these resources at its disposal after blackout.
- During the restoration process, the energization of long transmission lines and the capability of generators to support reactive power creates major problem.
- Sometimes, under the deregulated environment, the restoration process may involve private generators and multiple transmission companies.
- In such situations, the financial compensation for these private entities adds a new dimension to the restoration process.
- The overall coordination of network facilities owned by different entities and allocation of costs of various support entities is hard to determine.
- Therefore, the system operator can make long term contracts so as to procure black start capability. However, technical capabilities of contracted generators and their locations need to be considered.

16 What is the basic principle of marginal transmission pricing paradigm?---11 marks-Model exam

- According to this paradigm, only the new transmission costs caused by the new transmission customers will be considered for evaluating transmission charges for these customers.
- The existing system costs will remain the responsibility of utilities' present customers.



- In contrast to the philosophy of rolled-in methods, the embedded costs (sunk costs) are not taken into account, but the additional transmission cost a transaction causes is attributed to the transaction itself.
- Under this scheme, marginal cost of energy is calculated, which includes loss and network constraint components.
- Depending on the time-frame under consideration, the marginal costs can be classified as short-run and long-run.
- For short-run considerations, the transmission capacity is considered to be fixed, while for long-run pricing schemes, it is assumed that new capacities can be built.
- Thus, long-run marginal cost includes the reinforcement and expansion cost as well as the operating cost.
- Short-run marginal costs only reflect the operating costs of the existing facilities.

Short-run Marginal Cost Pricing (SRMC)

- The foundation of this methodology is based on the theory of spot pricing
- Under the marginal pricing schemes, the general idea is to model an electricity market with its various economical and technical specifications such as generator's cost functions, demand elasticity, generation limits, power flow limits, etc.
- Then, this system is optimized with the objective of maximizing the social welfare.
- An important outcome of this optimization is the nodal price at each load, which is popularly known as Locational Marginal Price.
- It reflects the temporal and spatial variation of the energy price relating to the energy demand.
- Because of losses and system security (line limits), a kWh of energy has different values at different busses of the network.
- Since wheeling is analogous to buying energy at one set of buses and selling it at another set, these spatial price differences determine the cost of wheeling.

Long-run Marginal Cost Pricing (LRMC)

- In the calculation of SRMC, it was assumed that the transmission capacity is fixed.
- For calculation of LRMC, this assumption is removed. To define formally, the LRMC are the costs of increasing the production by one unit, allowing changes in the overall system capacity, i.e., reinforcing the system.

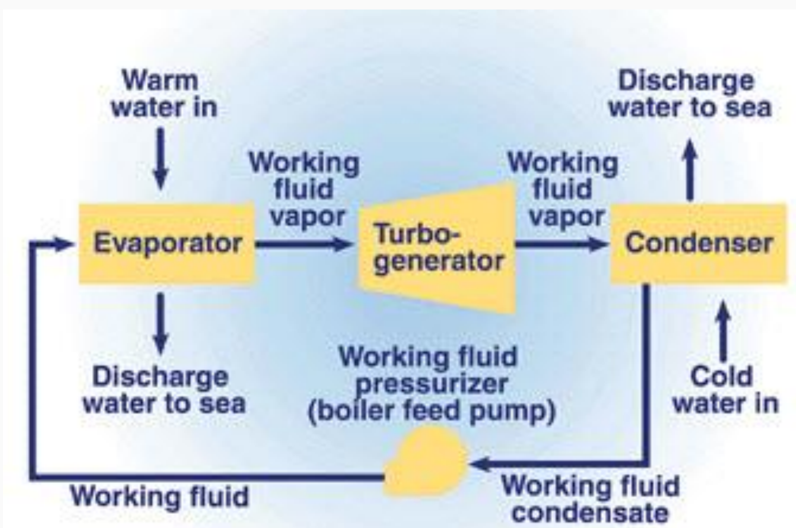
- For the optimal capacity of the network, LRMC and SRMC are equal.
- In this pricing methodology, the marginal operating and reinforcement costs of the power system are used to determine the prices for a transmission transaction.
- . The marginal reinforcement cost is calculated as follows
- "Over a long time horizon of several years, all transmission expansion projects are identified and their costs are taken into account. This cost is then divided over the total power magnitude of all new planned transactions to calculate the marginal reinforcement cost."

17 a) Summarize OTEC Cycle and its types in detail.(6 marks)

Ocean Thermal Energy Conversion (OTEC) system

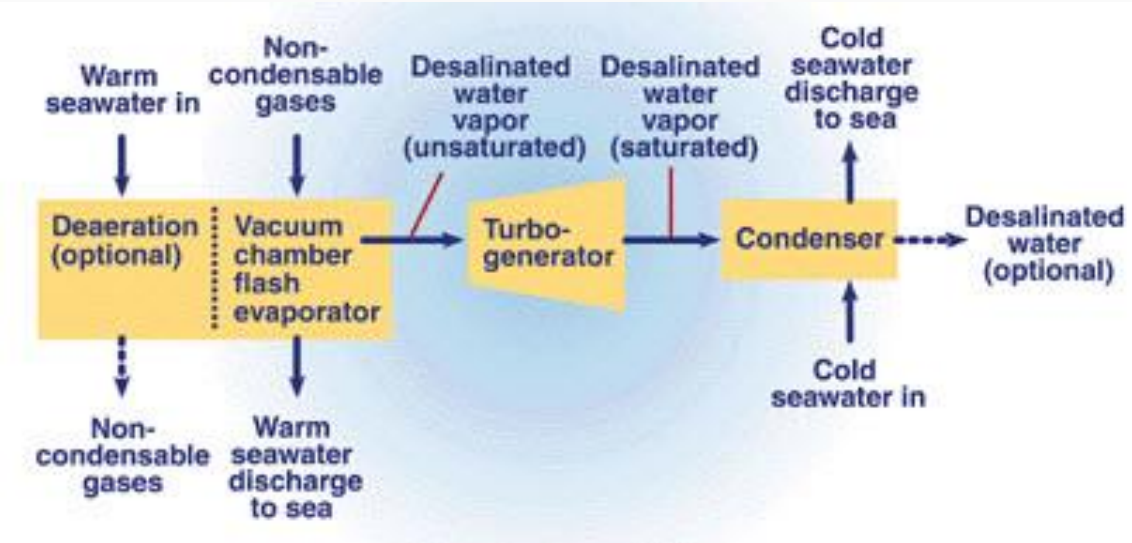
- Three types of OTEC systems can be used to generate electricity:
- Closed-cycle plants circulate a working fluid in a closed system, heating it with warm seawater, flashing it to vapor, routing the vapor through a turbine, and then condensing it with cold seawater.
- Open-cycle plants flash the warm seawater to steam and route the steam through a turbine.
- Hybrid plants flash the warm seawater to steam and use that steam to vaporize a working fluid in a closed system.

Closed-Cycle OTEC System



- In the closed-cycle OTEC system, warm seawater vaporizes a working fluid, such as ammonia, flowing through a heat exchanger (evaporator).
- The vapor expands at moderate pressures and turns a turbine coupled to a generator that produces electricity.
- The vapor is then condensed in another heat exchanger (condenser) using cold seawater pumped from the ocean's depths through a cold-water pipe.
- The condensed working fluid is pumped back to the evaporator to repeat the cycle.
- The working fluid remains in a closed system and circulates continuously.

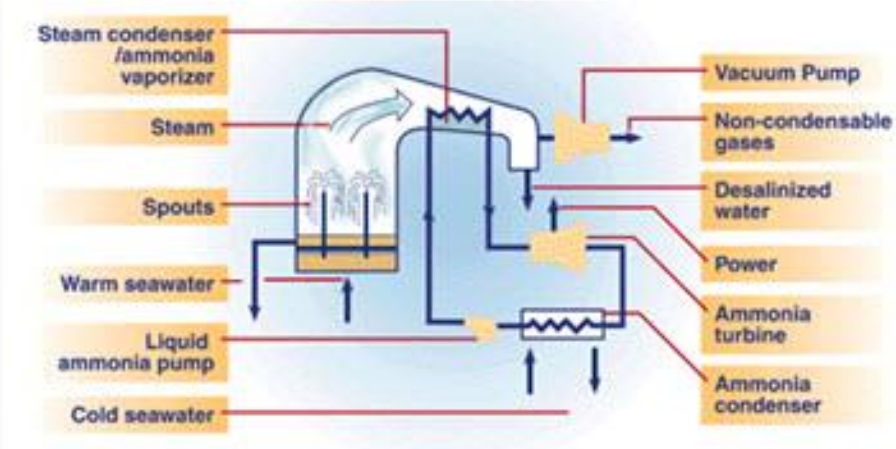
Open-Cycle OTEC System



- In an open-cycle OTEC system, warm seawater is the working fluid.
- The warm seawater is "flash"-evaporated in a vacuum chamber to produce steam at an absolute pressure of about 2.4 kilopascals (kPa).
- The steam expands through a low-pressure turbine that is coupled to a generator to produce electricity.
- The steam exiting the turbine is condensed by cold seawater pumped from the ocean's depths through a cold-water pipe.
- If a surface condenser is used in the system, the condensed steam remains separated from the cold seawater and provides a supply of desalinated water.

Hybrid OTEC System

- A hybrid cycle combines the features of both the closed-cycle and open-cycle systems.
- In a hybrid OTEC system, warm seawater enters a vacuum chamber where it is flash-evaporated into steam, which is similar to the open-cycle evaporation process.
- The steam vaporizes the working fluid of a closed-cycle loop on the other side of an ammonia vaporizer.
- The vaporized fluid then drives a turbine that produces electricity.
- The steam condenses within the heat exchanger and provides desalinated water.
- The electricity produced by the system can be delivered to a utility grid or used to manufacture methanol, hydrogen, refined metals, ammonia, and similar products.
- Some of the main components of an OTEC system are the heat exchangers, evaporators, turbines, and condensers.



b) **Explain one application of fuel cell? ---5 marks**

- Fuel cells are used for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas.
- They are also used to power fuel cell vehicles, including forklifts, automobiles, buses, trains, boats and submarines.

The Polymer Electrolyte Membrane (PEM) Fuel Cell

- These cells are also known as proton exchange membrane fuel cells (or PEMFCs).
- The temperature range that these cells operate in is between 50°C to 100°C
- The electrolyte used in PEMFCs is a polymer which has the ability to conduct protons.
- A typical PEM fuel cell consists of bipolar plates, a catalyst, electrodes, and the polymer membrane.
- Despite having eco-friendly applications in transportation, PEMFCs can also be used for the stationary and portable generation of power.

18 a) Give the difference between wave energy and tidal energy. Explain wave energy production in detail
Difference between wave energy and tidal energy ------------6 marks

Tidal Energy	**Wave Energy**
Harnessed from the rise and fall of sea levels	Harnessed from waves moving along the surface of the ocean
Caused by the gravitational pull of the moon and sun on the Earth	Caused by wind
Intensity is affected by location and position of the Earth	Intensity is affected by wind strength

	Often referred to as wave power
Types of tidal energy include kinetic and potential energy	Types of wave energy include kinetic energy
Harnessed using barrages, dams, tidal fences and tidal turbines	Harnessed using offshore and onshore systems
More reliable since it is based on the gravitational pull of the moon and sun	Less reliable since it is based on the effect of the strength of the wind on the surface of the water
Discontinuous source of energy that is generated for about 6 – 12 hours at a time	Continuous source of energy
Can disrupt migrating routes of birds and boating pathways and result in large amounts of fish kill	Effect on surrounding environments, ecosystems and communities are low
High construction costs but low maintenance costs	Extremely high start-up costs to design and develop the technology required

b) How tidal power is generated? Explain in detail-----5 marks

- Tidal energy is a form of hydropower that converts energy obtained from tides into useful forms of power, such as electricity.
- Tides are created by the gravitational effect of the moon and the sun on the earth causing cyclical movement of the seas.
- Tidal energy is a form of power produced by the natural rise and fall of tides caused by the gravitational interaction between Earth, the sun, and the moon.
- Tidal currents with sufficient energy for harvesting occur when water passes through a constriction, causing the water to move faster.
- Using specially engineered generators in suitable locations, tidal energy can be converted into useful forms of power, including electricity.
- Other forms of energy can also be generated from the ocean, including waves, persistent ocean currents, and the differences in temperature and salinity in seawater.
- Suitable locations for capturing tidal energy include those with large differences in tidal range, which is the difference between high tide and low tides, and where tidal channels and waterways become smaller and tidal currents become stronger.

UNIT-V

19 Explain the different factors to fix tariff in deregulated markets (11 marks)

The rate at which electrical energy is sold to the consumers is termed as 'tariff. ' The cost of generation of electricity will depend upon various factors such as **Connected Load, Maximum Demand, Load factor, Demand Factor, Diversity Factor, Plant Capacity Factor and Use Factor**

Factors Involved In Deciding an Electricity Tariff

- The tariff should be such that the total cost of generation, transmission, and distribution is recovered.
- It should earn a reasonable profit.
- It must be fair and at a reasonable to the consumers.
- It should be simple and easy to apply.
- It should be attractive than a competitor.

Various Types of Electricity Tariff

1. Simple Tariff

- In this type of tariff, a fixed rate is applied for each unit of the energy consumed. It is also known as a uniform tariff.
- The **rate per unit of energy does not depend upon the quantity** of energy used by a consumer. The price per unit (1 kWh) of energy is constant.
- This energy consumed by the consumer is recorded by the energy meters. Graphically, it can be represented as follows:

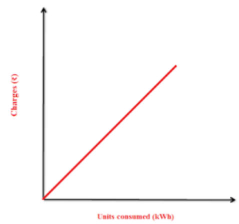


Figure : Simple Tariff

Advantages:

- Simplest method
- Easily understandable and easy to apply
- Each consumer has to pay according to his utilization

Disadvantages:

There is no discrimination according to the different types of consumers.

- The cost per unit is high.
- There are no incentives (an attractive feature that makes the consumers use more electricity.)
- If a consumer does not consume any energy in a particular month, the supplier cannot charge any money even though the connection provided to the consumer has its own costs.

Application

generally applied to tube wells used for irrigation purposes.

2. Flat Rate Tariff

- In this tariff, different types of consumers are charged at different rates of cost per unit (1kWh) of electrical energy consumed.

- Different consumers are grouped under different categories. Then, each category is charged money at a fixed rate similar to Simple Tariff.
- The different rates are decided according to the consumers, their loads and load factors. Graphically, it can be represented as follows:

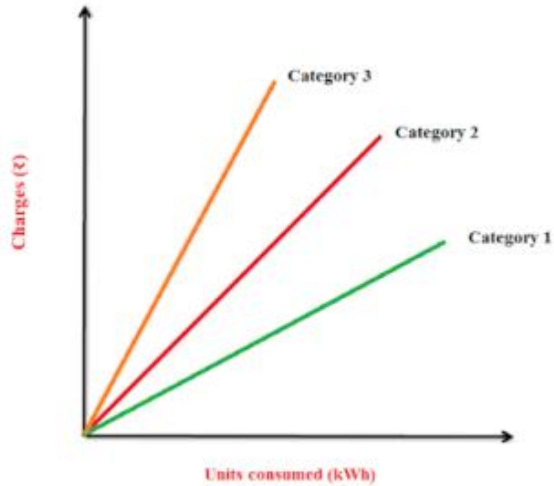


Figure : Flat Rate Tariff

Advantages
More fair to different consumers.
Simple calculations.
Disadvantages

- A particular consumer is charged at a particular rate. But there are no incentives for the consumer.
- Since different rates are decided according to different loads, separate meters need to be installed for different loads such as light loads, power loads, etc.
- This makes the whole arrangement complicated and expensive.
- All the consumers in a particular “category” are charged at the same rates. However, it is fairer if the consumers that utilize more energy be charged at lower fixed rates.

Application
generally applied to domestic consumers.

3. Block Rate Tariff

- In this tariff, the first block of the energy consumed (consisting of a fixed number of units) is charged at a given rate and the succeeding blocks of energy (each with a predetermined number of units) are charged at progressively reduced rates.
- The rate per unit in each block is fixed.

For example, the first 50 units (1st block) may be charged at 3 rupees per unit; the next 30 units (2nd block) at 2.50 rupees per unit and the next 30 units (3rd block) at 2 rupees per unit.

- **Advantages**
  Only 1 energy meter is required.

- Incentives are provided for the consumers due to reduced rates. Hence consumers use more energy. This improves load factor and reduces cost of generation.
- **Disadvantages**
  If a consumer does not consume any energy in a particular month, the supplier does not charge any money even though the connection provided to the consumer has its own costs.
- **Application**
  Generally applied to residential and small commercial consumers.

Graphically, it can be represented as follows:

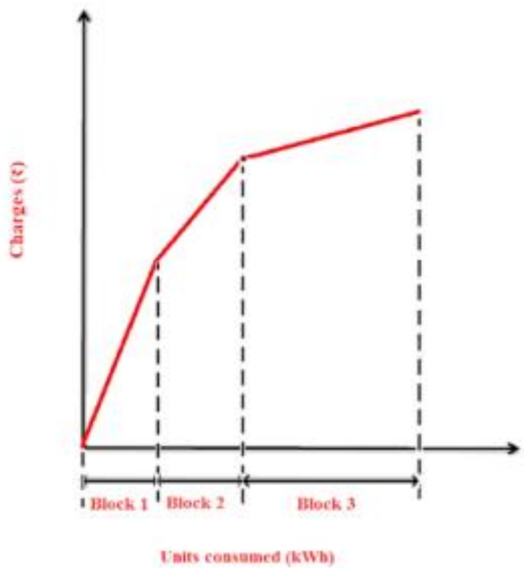


Figure : Block Rate Tariff

4 Two Part Tariff

In this tariff scheme, the total costs charged to the consumers consist of two components: fixed charges and running charges. It can be expressed as:

Total Cost = [A (kW) + B (kWh)] Rs.

Where, A = charge per kW of max demand (i.e. A is a constant which when multiplied with max demand (kW) gives the total fixed costs.)

B = charge per kWh of energy consumed (i.e. B is a constant which when multiplied with units consumed (kWh), gives total running charges.)

Advantages

- If a consumer does not consume any energy in a particular month, the supplier will get the return equal to the fixed charges.
- **Disadvantages**
  Even if a consumer does not use any electricity, he has to pay the fixed charges regularly.
- The maximum demand of the consumer is not determined. Hence, there is error of assessment of max demand and hence conflict between the supplier and the consumer.

Application

Generally applied to industrial consumers with appreciable max demand.

5. Maximum Demand Tariff

In this tariff, the energy consumed is charged on the basis of maximum demand. The units (energy) consumed by him is called maximum demand.

The max demand is calculated by a maximum demand meter. This removes any conflict between the supplier and the consumer as it were the two part tariff. It is similar to two-part tariff.

Application
Generally applied to large industrial consumers.

6. Power Factor Tariff

- In this tariff scheme, the power factor of the consumer's load is also considered.
- For optimal operation, the p.f must be high.
- Low pf will cause more losses and imbalance on the system. Hence the consumers which have low pf loads will be charged more.
- It can be further divided into the following types:

  KVA Maximum Demand Tariff
- In this type of tariff, the fixed charges are made on the basis of maximum demand in kVA instead of KW.

  power factor = kW / kVA
- Hence, the pf is inversely proportional to kVA demand.
- Hence, a consumer having low power factor load will have to pay more fixed charges.
- This gives the incentive to the consumers to operate their load at high power factor.
- Generally, the suppliers ask the consumers to install power factor correction equipment.

  KW And KVAR Tariff
- In this tariff scheme, the active power (kW) consumption and the reactive power (kVAR) consumption is measured separately.
- A consumer having low power factor load will have to pay more fixed charges.

  Sliding Scale Tariff
- In this type of tariff scheme, an average power factor (generally 0.8 lagging) is taken as reference.
- Now, if the power factor of the consumer's loads is lower than the reference, he is penalized accordingly.
- Hence, a consumer having low power factor load will have to pay more fixed charges.
- Also, if the pf of the consumer's load is greater than the reference, he is awarded with a discount. This gives incentives to the consumers. It is usually applied to large industrial consumers.

7. Three Part Tariff

In this scheme, the total costs are divided into 3 sections: Fixed costs, semi-fixed costs and running costs.
Total Charges = [A + B (kW) + C (kWh)]
Where, A = fixed charges,
B = charge per kW of max demand (i.e. B is a constant which when multiplied with max demand (kW) gives the total fixed costs.)

C = charge per kWh of energy consumed (i.e. C is a constant which when multiplied with units consumed (kWh), gives total running charges.)
Application: This type of tariff is generally applied to big consumers.

20 List the salient Features of Indian Electricity Act 2003 (model exam, IT-2)---11 marks

The main basic features of the Electricity Act, 2003 are

1. There is a provision for private transmission licenses.
2. Distribution licenses would be free to undertake generation.
3. There would be a Transmission Utility at the central and State level.
4. Generation is being delicensed not as before and captive generation is freely permitted.
5. The State Electricity Regulatory Commission may permit open access in distribution in phases.
6. There is direct commercial relationship between the consumer and generating company or a trader.
7. There is a provision for transfer scheme.
8. System for generation as well as distribution will be permitted in the rural and remote areas.
9. There is a provision for Constitution of Central Electricity Authority.
10. There is provision for Constitution of Central Commission as well as the State Commission.
11. There is provision for Constitution of Central Advisory Committee as well as the State Advisory Committee.
12. There is provision for Establishment of Fund by the Central Government and the State Government.
13. There is provision for Establishment of Appellate Tribunal for adjudicating the grievances face by the Consumers etc.
14. There is provision for Offences and Penalties to be imposed on the person/ persons on the charge of Theft of Electricity such as materials, damaging work, stolen property etc.
15. There is provision for Exclusion of Jurisdiction of the Civil Court for speedy adjudication.
16. There is provision for Constitution of Special Courts for the trial of special cases.
17. There is provision for Arbitration open to the Consumers, Company etc. for arriving settlement with less time and resources.