CMR
INSTITUTE OF
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Improvementt Test - I

Sub:	POWER SYSTEM PLANNING							Code:	10EE761
Date:	19 / 11 / 2016	Duration:	90 mins	Max Marks:	50	Sem:	7	Branch:	EEE

Answer Any **FIVE** FULL Questions

		Marks	OBE	
			CO	RBT
1	List out the different electricity regulation acts.	[10]	CO1	L1
2	Describe the structure of power system with respect to various components and types.	[10]	CO3	L2
3	Explain co-generation and its categories.	[10]	CO2	L4
4	Discuss on power system distribution planning.	[10]	CO3	L2
5	Explain power pooling & power trading.	[10]	CO3	L4
6	Discuss on rural electrification investment.	[10]	CO4	L2
7	Explain problem description with respect to optimization techniques.	[10]	CO6	L4

Course Outcomes		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1:	Explore the objectives of national and regional planning.	1	-	-	-	-	-	-	-	1	-	-	-
CO2:	Analyze and distinguish load forecasting techniques.	1	-	-	-	1	1	-	1	-	-	-	-
CO3:	Describe Generation transmission and distribution planning and analyze the related economical concepts.	2	-	-	-	1	-	-	1	1	-	-	-
CO4:	Examining Global energy concepts.	1	-	-	-	2	-	-	2	1	-	-	-
CO5:	Asses and infer Load management Schemes.	3	-	-	-	1	1	-	1	-	-	-	-
CO6:	Formulate cost optimization methods.	3	-	1	-	-	-	-	1	-	-	-	-

Cognitive level	KEYWORDS
L1	List, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.
L2	summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
L3	Apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover.
L4	Analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer.
L5	Assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize.

PO1 - *Engineering knowledge*; PO2 - *Problem analysis*; PO3 - *Design/development of solutions*; PO4 - *Conduct investigations of complex problems*; PO5 - *Modern tool usage*; PO6 - *The Engineer and society*; PO7- *Environment and sustainability*; PO8 – *Ethics*; PO9 - *Individual and team work*; PO10 - *Communication*; PO11 - *Project management and finance*; PO12 - *Life-long learning*

Answer key:

1ans:

Concerns of regulatory bodies :

- Price setting, consumer tariff, wheeling charges, long term bulk power purchase agreements
- Quality of service standard and monitoring
- Compliance with public service obligations
- Dealing with consumer complaints
- Ensuring fair and open competition
- Monitoring investment
- Repair of infrastructure
- Third party use of infrastructure

Objective of regulatory bodies :

- Improve efficiency
- Uniformity of tariff
- Develop and manage integrated energy systems
- Competitative power development

Rules by regulatory bodies :

- grid connection
- Interstate tariff
- Power pooling
- Power banking / selling with public or private sector
- Competative tariffs from private parties
- Pass energy conservation laws
- Access to private generators
- Technical aspects of operation and despatch of power

- **Indian Telegraphic Act,1885**
  - Previlages and power of govt to place telegraphic lines / posts
  - Penalties and provisions regarding electrical lines

- **India Electricity Act, 1910 :** For laws relating supply and use of electrical energy
  - **Licenses :** grant / revocation / amendment / renewal / annual account
  - **Works :** laying of lines / notifications / permission / compensation
  - **Supply :** licensees permission to enter premises / obligation to supply energy / restriction / powers of state on licensee / power to control distribution and consumption of energy / metering / discontinuance
  - **Tranmisson and use of energy by non licensees :** sanctions / control of transmission and use
  - **General protective clause :** protection of public infrastructure / notice of accidents / prohibition of connection / power of govt . To interefere
  - **Administration and rules :** advisory boards / appointment of electrical inspectors
  - **Criminal offenses and procedure :** theft / penalty for wastage by consumers / penalty of unauthorised supply of energy / penalty for tampering with meters
  - **Supplementary provisions :** recovery of sums / protection of acts done in good faith

ELECTRICITY ACTS

- **Indian Electricity rules, 1956**
  - Authorization of electric installations
  - Inspection of electric installations
  - Licensing
  - General safety precautions
  - General conditions relating to supply and use of energy
  - Electric supply lines, system and apparatus for low, medium, high and extra high voltages
  - Overhead lines
  - Electric traction
  - Additional precautions for mines and oil fields
  - Miscellaneous provisions

PROJECT CLEARANCES

- **Cost estimates :**
  - Limits are set for each capacity group – justify the investment

- **Techno-economic clearance by CEA :**
  - Possible economic output
  - Examination of rivers / dams for hydro projects
  - Reasonableness of the scheme
  - Site location for optimum utilization of fuel resources, distance from load centres, environmental considerations

PROJECT CLEARANCES

- **Publications :**
  - Schemes of operation, tariff plans

- **SEB Clearance :**

Water availability	Pollution clearance
Forest clearance	Civil aviation clearance and chimney height
Registration of company	Rehabilitation and settlement of displaced families
Land availability	Financing / investment approval
Transportation of fuel	

Forest conservation act, 1980 : Guidelines for power lines

- Where routing of power lines through the forest areas cannot be avoided, these should be aligned in such a way that it involves least amount of tree cutting
- As far as possible, the route alignment through forest areas should not have any line deviation
- The maximum width of right of way for the power lines on forest land should be as follows :

Line voltage(kV)	Width of RoW (m)	Line voltage(kV)	Width of RoW (m)
11	7	132	27
33	15	220	35
66	18	400	52
110	22	800	85

- Below each conductor, width clearance of 3m would be permitted for taking the swinging of string equipment. The trees on such strips would have be felled out would be allowed to regenerate later
- Felling, pruning of trees will be done with the permission of local forest officers whereever necessary.
- One outer strip shall be left clear to permit maintainance of the line
- In the remaining width, trees will be felled or looped to the extent reqd, for preventing electrical hazards by maintaining the following : (sag and swing of the conductors are to be kept in view while working out the minimum clearance)

Line voltage(kV)	Min clearance between trees and conductors (m)	Line voltage(kV)	Min clearance between trees and conductors (m)
11	2.6	132	4.0
33	2.8	220	4.6
66	3.4	400	5.5
110	3.7		

3ans:

COGENERATION / CAPTIVE POWER (3.5):

- There is large scope for cogeneration → 50000MW in India
- in industries such as sugar, textile, alcohol, paper, petro-chemicals and metallurgical.
- It should be made mandatory for **cement, steel, aluminium, fertilizers, chemical plants** and other heavy industry to install captive power.
- Consumers could **utilize the waste heat** produced in heavy power-intensive industries having load more than 5 MW, such as steel, aluminium plants.

COGENERATION / CAPTIVE POWER (3.5):

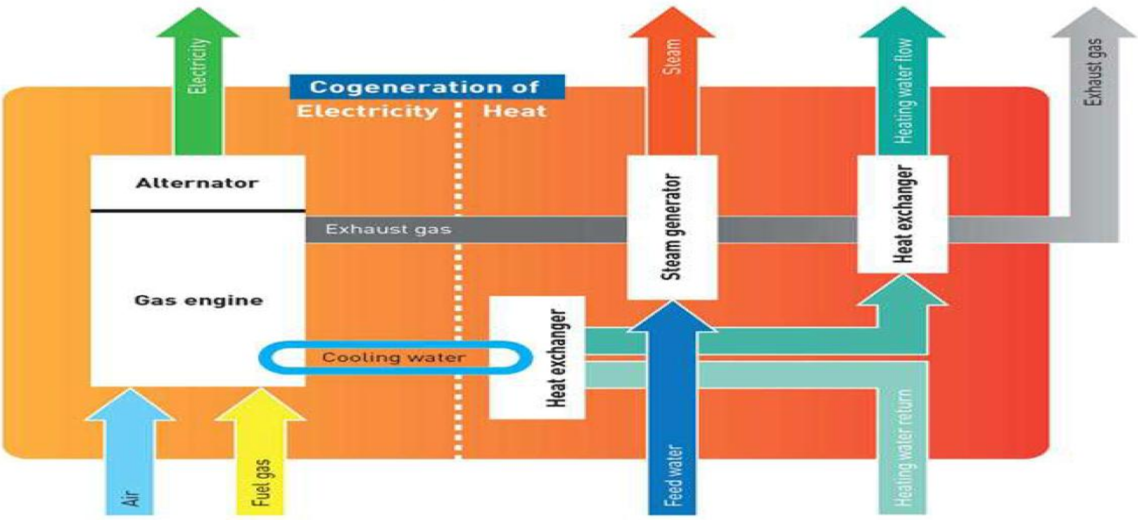
Potential industries	Mandatory industries
Sugar	Cement
Textile	Aluminum
Alcohol	Fertilizers
Paper	Chemical plants
Petrochemicals	Heavy industries
Metallurgical	Induction / arc furnace

COGENERATION / CAPTIVE POWER (3.5):

- They must **install cogeneration plants/captive power generation** plants for tl sake of economical power generation.
- A **cogeneration facility** produces **electrical energy** and **other forms** of useful **thermal energy** (such as heat and steam) used for industrial, commercial, heating or cooling purposes.
- In the **combustion of fuel**, **energy is released** which is used for **heating** or to perform some useful form of work.
- Not **all of the energy** that is produced can be used; some of it is **wasted.**
- A **cogeneration facility recaptures** some of the waste energy that otherwise would escape and puts it to **useful purpose**.

COGENERATION / CAPTIVE POWER (3.5):

- **Cogeneration** can be used in almost **any industry** with some type of thermal need.
- **small packaged cogeneration units** ⟶ for **hospitals, shopping complexes and small manufacturing** firms



COGENERATION / CAPTIVE POWER (3.5):

- **Cogeneration systems** are **more expensive .**
- Cost more to operate and maintain than systems that produce only **thermal energy**.

- factors to consider in deciding on cogeneration:

1. Degree of waste recovery
2. duty cycle
3. capital cost
4. fuel and electricity prices
5. Taxes
6. reliability
7. size

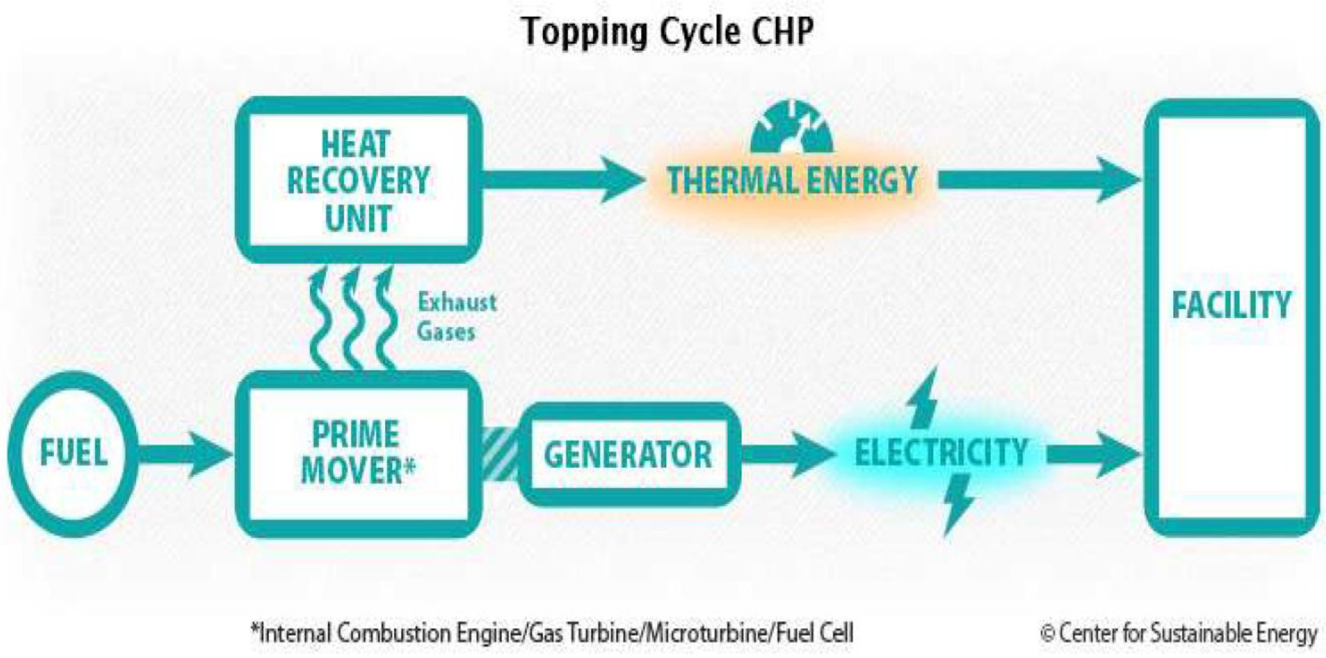
COGENERATION / CAPTIVE POWER (3.5):

- **Two basic processes** a cogeneration facility may utilize.
    1. topping cycle process - most common
    2. **bottoming cycle process**

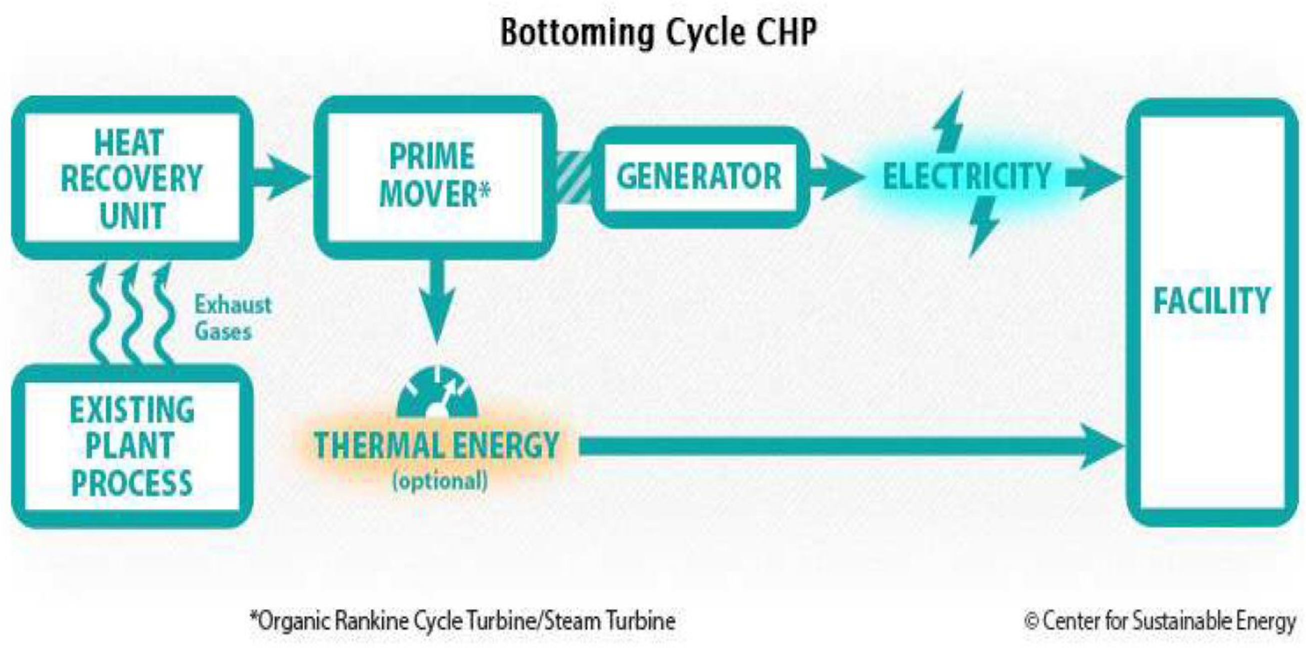
- In the topping cycle process, electricity is produced first and the **waste energy being recovered** is in the form of thermal energy.

- In the **bottoming cycle**, the thermal energy is first used in a process and the waste energy recovered from that process is used to produce electricity.

COGENERATION / CAPTIVE POWER (3.5):



COGENERATION / CAPTIVE POWER (3.5):



5ans:

POWER POOLING AND TRADING

- A power pool is a situation where output from different power plants are "pooled" together.
- dispatched according to this "merit order" to meet demand.
- Power pooling is used to balance electrical load over a larger network (electrical grid) than a single utility.
- With respect to pool terminology,
- tight and loose power pools (as termed in the US)
- relate to the centralization and mandatory nature of power pooling arrangements.
- power pools in the US → New York Power Pool (NYPP)
- New England Power Pool (NEPOOL)
- The pool serves two main functions: price determination and physical trading.
- Price determination is like → stock exchange or an antique auction
- the prices are determined by the bids followed by the actual exchange of stock .

POWER POOLING AND TRADING

- Power cannot be stored, hence generation = demand
- **Sample system of UK :**
  - Regional and national grid companies form a **pool**
  - The companies compete for wholesale generation
  - Energy is sold in bulk in wholesale market
  - **Spot price** is determined for **half-hour basis** in national power load curve period through competitive bidding by individual generators
  - Pool is a mechanism to allow trading or sharing between power utilities and generators
  - Long term contracts in sales and purchase are made between utilities and generating companies based on **set of rules evolved.**
  - Spot trading in **short term market** reflect supply and demand on short term basis

POWER POOLING AND TRADING

Settlement system in UK :

- Price and payments are calculated under **pool wheeling** arrangements

- **Grid operator** seeks to **schedule & dispatch** generating units subject to constraints , to meet demand and maintain reserve.

- Before 10am on the day ahead of actual operation, each utility submits to the grid operator an offer for generating sets :
  - Generators' price
  - Availability
  - Operating characteristics of the set

POWER POOLING AND TRADING

- All offers of the period + demand forecast + planned reserve are fed to the computer to match the demand and supply at least cost.

- The **schedule is generated** – pool purchase price (PPP) is decided for **half hour**

- PPP consists of :
  - system marginal price :
    - **price derived from offer prices** of the marginal generating sets scheduled in the unconstrained schedule for the relevant period.
  - Capacity element :
    - calculated according to **Loss of Load Probability (LOLP)**

POWER POOLING AND TRADING

- Pool input price – national grid company pays to generators
- Pool output price – price charged from public electricity suppliers

- Pool is a spot market which operates in real time.

- **Tariff** for retail market is decided observing the **pool output system**
- The consumers are made aware of efficiency and load management through **tariffs.**

- Consumers to purchase power from renewable energy sources- Non fossil fuel obligations
- The public electricity suppliers purchase electricity from the RES generators

POWER POOLING AND TRADING

- On any day , payments must be balanced in the pool

- Pool selling price (PSP)– to be recovered from the suppliers

- PPP-PSP = uplift

- Uplift is to pay for :
  - Cost of ancillary services
  - Payments for reserve
  - Difference between unconstrained scheduling and

POWER POOLING AND TRADING

- USA:
  - Vertically integrated **utilities in each state** with **independent power generators**
  - Sell bulk power to utilities
  - Competition to construct and operate new power stations
  - Limited spot market and wholesale generation
  - Utilities have monopoly in retail supplies

- India :
  - Yet to formulate commercial guidelines for wheeling of power
  - A **rational tariff** structure to encourage **selling and buying** of power
  - Measures are devised to discourage high frequency operation of grid

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2ans:

STRUCTURE OF POWER SYSTEM:(1.7)

- The basic system consists of **energy resources** such as **hydro, coal, gas** etc.,
- a **prime mover, a generator and a load**.
- Some sort of **control system** is required for supervising it.

- The **prime mover may** be a **steam driven turbine, a hydraulic turbine or an internal combustion** engine.
- prime movers :**energy in the form of heat, falling water or fuel**

↓

into **rotation of the shaft**

↓

drives the **generator.**

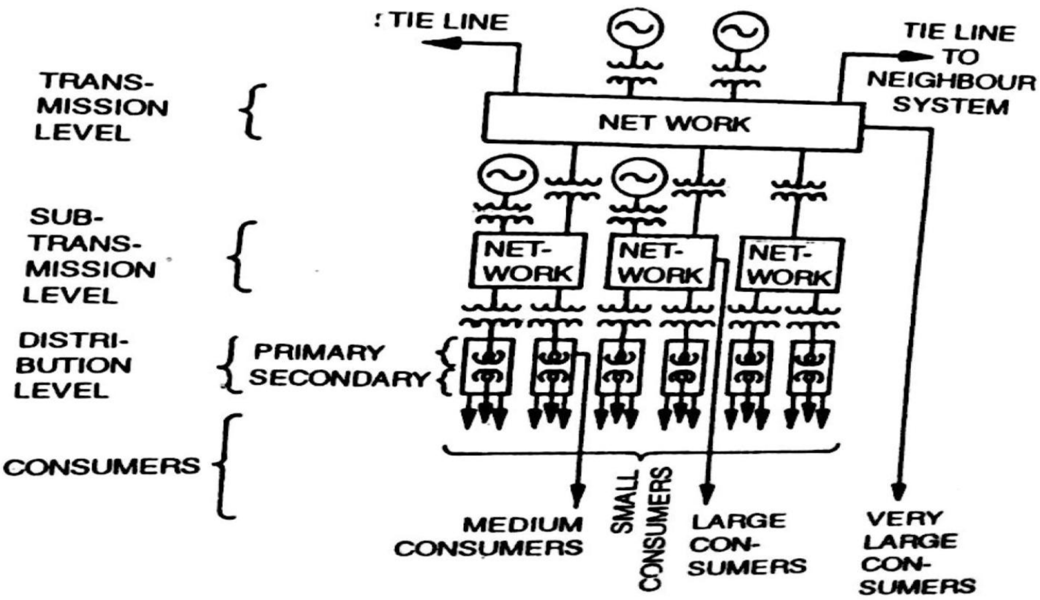
STRUCTURE OF POWER SYSTEM:(1.7)

- **generator** may be **alternator or a d.c. machine**.
- Electrical **load** on the generator may be **lights, motors, heat or other devices**
- The **control system** functions: a) to keep the **speed of the machine constant**
  b) the **voltage** within prescribed **limits**
  c)**excitation** within **the generator capability**.

- The **active power** (MW) is regulated by frequency (speed) control
- The **reactive power** (MVAr) and voltage is regulated by excitation control.
-

STRUCTURE OF POWER SYSTEM:(1.7)

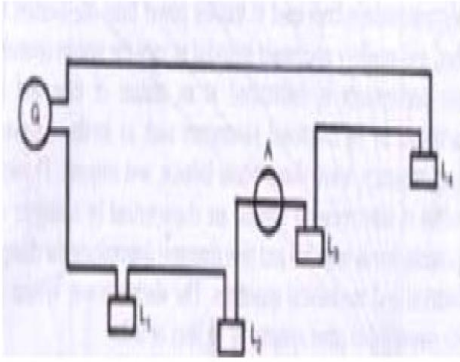
Power system components



STRUCTURE OF POWER SYSTEM:(1.7)

2. loop system :

- all loads will continue to be served even if one line section' is put out of service.
- In normal operation the loop may be open at some point at **A** as shown in the figure.
- In case a line section is to be taken out, the loop is first closed at **A**
- the line section is put on shut down.
- In this way **no service interruption occurs.**

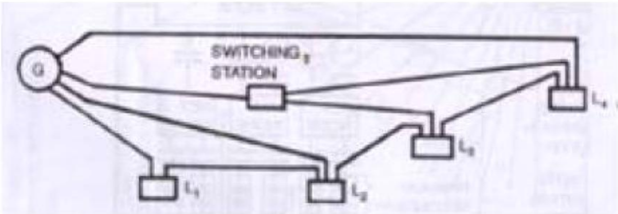


Loop System

STRUCTURE OF POWER SYSTEM:(1.7)

3. Network of line

- the **same loads being served by a network**.
- arrangement has a **higher reliability** as each load has **two or more circuits** of supply
- The **sub transmission and distribution circuits** are commonly designed as radial or loop circuits.
- The **high voltage transmission lines** are generally laid as interconnected or networks.
- Transmission and distribution are distinguished by their voltage levels.
- general, transmission systems have **bulk power handling capability,** and relatively **long lines .**
- connecting **generating stations** to **load centers** of the utilities.



Network of Lines

4ans:

DISTRIBUTION NETWORK:(4.1)

- Sub transmission system:
  - 33 – 220 KV
  - Delivers **energy to distribution** substation
- Distribution substation :
  - converts to lower **primary distribution system voltage**
  - **Boosts voltages** for **better voltage regulation** of primary voltage
- Primary circuits of feeders :
  - 11-33 KV
  - Supplies bulk load directly and distribution transformers
- Distribution transformers :
  - 10 – 2500 KVA
  - Transform the **primary voltage** to **utilization voltage at 110 – 440 V**
- Secondary circuits :
  - carry energy from the **D.T along streets**
- Service lines :
  - deliver energy from secondary circuits to consumer premises

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STRATEGY:

- **SEB** : To provide **transmission systems** for **state grids**
- **POWERGRID :**
  - **To lay the transmission system network** for **power transfer by central sector**
  - For **strengthening regional power grids**
  - **Formation** of **national power grid to transfer power across various regions .**
- **Private companies** can also develop the transmission system
- **Transmission network planning :**
  - Should be with **a long and medium term perspective**
  - Should have an integrated approach to **transfer power from all sources** to all **beneficiaries**
  - **Optimal design** with **reliability**, **security** and **economy** in mind
  - **Good voltage profile** should be maintained
  - Network should **integrate within the region** and **inter-regions**
  - Configuration should be such that **optimal dispatch** is possible

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THERMAL LOADING:

- Loading limit is decided by :
  1. **ambient temperature** – varies with location and season
  2. **maximum permissible conductor temperature**-specified for standard sizes

		Loading(MVA) based on max. conductor temp of	
conductor	Ambient temp	65 deg	70 deg
258 sq. mm ACSR	40 deg	225	257
	45 deg	189	225
345sq. mm ACSR	40 deg	943	1077
	45 deg	785	943

220 k V LINES

- ## DESPATCHABILITY : (LOADING & outage)

- System should be planned such that :
  - It is **self sufficient (regional)** as well as **suitable for sharing** with neighbors **(inter-regional)**
  - Maximum **power angular separation between 2 buses** < **40 deg** for **steady state**
  - Should **withstand outage of 2 circuits** of **220 KV** system/1 circuit of 400KV / 1 pole of HVDC bipolar / 1 EHV transformer without load shedding or rescheduling of generation

7ans:

1. PROBLEM DEFINITION

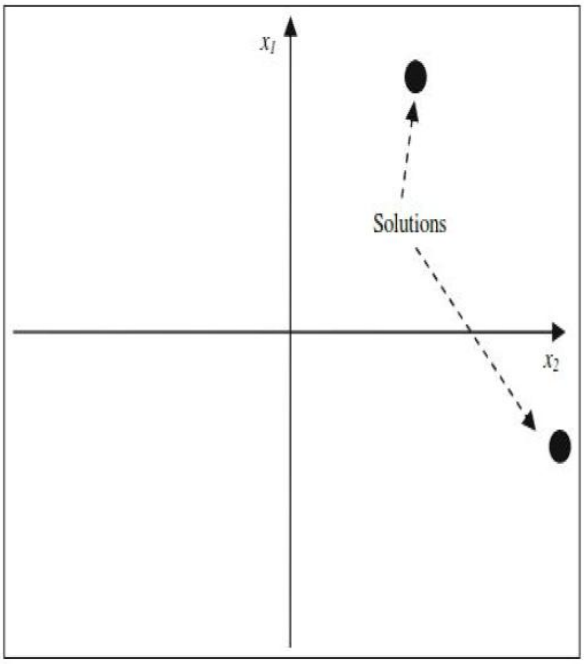
b) Constraints functions

Real life optimization **limitations apply to solution space**
(technical, economical, environmental)

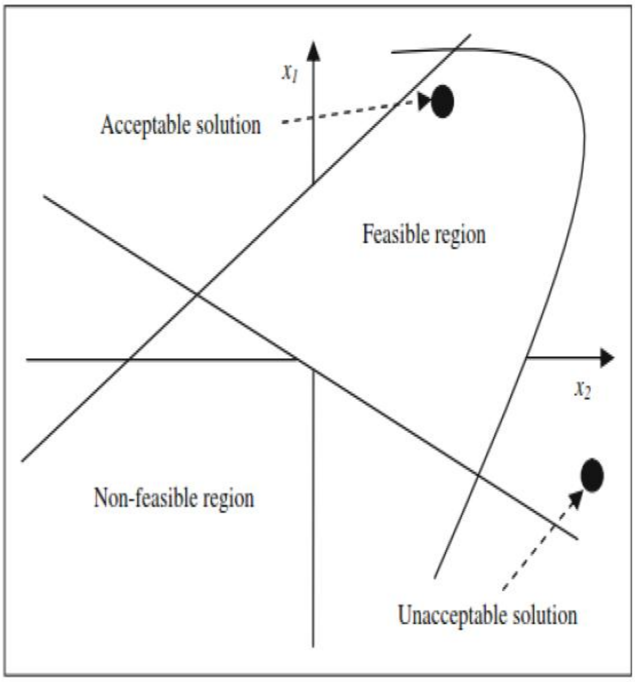
⬇

constraints

- Solution space is divided into **acceptable (feasible)** & **unacceptable (non-feasible)** regions.



ie solution space for a two-dimensional case



Feasible and non-feasible regions due to constraints

c) Objective function

Decision maker

- Numerous points of feasible region ⟶ select most desirable
- Desirable func should be defined.
- ⬇
- **Maximizing x_1**
- **Minimizing x_2**

2. MODELLING

$$\min_{x} C(x)$$
$$\text{s.t. } f(x) = 0$$
$$g(x) \leq 0$$

where x is the decision variable,
C(x) is the objective function
f(x) is equality constraint. and

g(x) is the inequality constraint.

3. SOLUTION ALGORITHM

- If both the **objective functions** and **the constraints** are linear functions of x ⟶ **Linear Programming (LP) problem.**
- the objective function and/or the constraints are **nonlinear** ⟶ **Non Linear optimization Problem (NLP)**
- if x is of **integer** type ⟶ **Integer Programming (IP).**
- the variables are both **real and integer** ⟶ **MILP (Mixed Integer Linear Programming)**

Linear Programming (LP)

- Any LP problem can be stated as a **minimization problem** ,
  maximizing C(x) is equivalent to **minimizing (-C(x)).**
- All constraints may be stated as **equality type**

$$a'_1x_1 + a'_2x_2 + \cdots + a'_nx_n < b' \qquad a''_1x_1 + a''_2x_2 + \cdots + a''_nx_n > b''$$

can be transformed to equality constraints, given by

$$a'_1x_1 + a'_2x_2 + \cdots + a'_nx_n + x'_{n+1} = b'$$

$$a''_1x_1 + a''_2x_2 + \cdots + a''_nx_n - x''_{n+1} = b''$$

x'_{n+1} and x''_{n+1} are **nonnegative variables**, known as **surplus variables.**

- All decision variables can be considered **nonnegative**

$$x_j = x'_j - x''_j \qquad x'_j \geq 0 \text{ and } x''_j \geq 0$$

Non Linear Programming (NLP)

- If objective function & constraints are non-linear -- NLP
- **Constrained problems** can be converted into **unconstrained one**
- Two solution methods

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1. **direct search (or non-gradient) methods**

- do not use the partial derivatives of the objective function and are suitable for simple problems involving a relatively small number of variables

2. **descent (or gradient) methods**

requires the first and higher order derivatives of the objective function and are more efficient than the direct methods.

- **iterative in nature** and start from an initial trial solution
- **moving stepwise in a sequential manner** towards the optimum solution

constrained case

- **Two types**

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1. **direct method** :- constraints are handled in an explicit manner

Eg: constraint approximation method

objective function and the constraints are linearized about some point and solved using LP techniques

2. **Indirect method** :- constrained problem is converted into a sequence of unconstrained problems

Eg: penalty function method

converts the problem into an unconstrained type, classified as interior and exterior penalty function methods, In both, they move towards the desired solution.

Dynamic Programming (DP)

- **Widely used technique** in power system studies.
- **Mathematical technique** used for **multistage decision problems**.
- **optimal decisions** are made
- **over some stages**
- **Different time, different spaces, different levels**
- **Imp point** is that **O/P** of one stage should be **I/P** of **next serial stage**
- **Overall objective** function is to be **optimized over all stages**
- E.g.: a power system with following information

➢ **4 generation units** are available each may be **ON/OFF**

Possible combinations are 1111, 1101, 1001, 0011…..

➢ **unit efficiencies are diff** --- so system load is low , ➡so higher efficiency units are used to supply load.

➢**Load varies 24 hrs**--- changing at every hour (stage)

- So final solution looks like

1	2	3	4		15		23	24
1011	1011	0011	1011	....	1101	....	1111	1110

Units combinations over the 24-h period

- Unit 1 is ON at hrs 1& 2 , OFF at 3, again ON at 4 etc
- So our solution is not practical.
- No of combinations is $2^4 - 1 = 15$.
- For 24 hrs no of combinations will be $(15)^{24}$
- if no of units are 100 ➡ $2^{100} - 1$ ➡ Impossible!!! Multistage ⤵ decomposed single stage problems

Integer programming method

- **Decision variables** may take any real value
- If limited to an integer value → IP
- Eg. **decision variable** is no of generation units– real value is meaningless
- If **all decision variables are integer type** → **IP Problem**
- If some decision variables are integer type & others are non-integer type →
- MIXED INTEGER PROGRAMMING PROBLEM

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