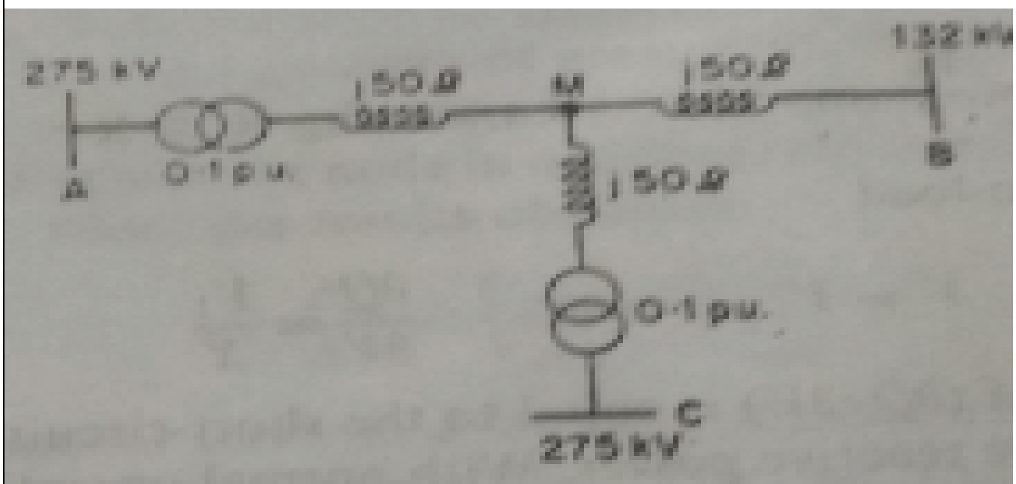
CMR INSTITUTE OF TECHNOLOGY	USN	

Internal Assesment Test 3 – June-2022								
Sub:	Power System operation & Control						Code:	18EE81/17EE81
Date:	17/06/2022	Duration:	90 mins	Max Marks:	50	Sem: 7	Section:	A & B

Note: Answer any **FIVE FULL** Questions

Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1.	Three supply points A,B and C are connected to a common bus bar M. Supply point A is maintained at a nominal 275 kV and is connected to M through a 275/132 kV transformer (0.1 pu reactance) and a 132 kV line of reactance 50 Ω.Supply point B is nominally at 132 kV and is connected to M through a 132 kV line of 50 Ω reactance .Supply point C is nominally at 275 kV and is connected to M by a 275/132kV transformer (0.1 pu reactance)and a 132 kV line of 50 Ω reactance. If at a particular system load, the line voltage of M falls below the nominal value 5 kV, calculate the magnitude of the reactive volt ampere required in M to establish the original voltage. The pu values are expressed on a 500 MVA base. 	[10]	CO5	L4
2.	Explain about the generation and absorption of reactive power in electrical power systems	[10]	CO5	L2
3.	With the help of flowchart explain contingency analysis	[10]	CO6	L3
4.	Explain about linear sensitivity factors	[10]	CO6	L2
5.	Briefly explain the different methods of reactive power injection in power systems	[10]	CO5	L2

<table>
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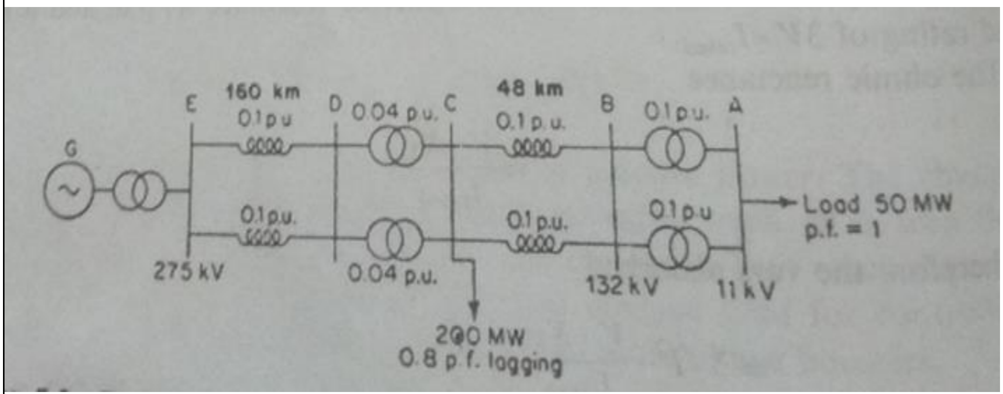
<td>6.</td>
<td>In the radial transmission system shown in fig ,all pu values are referred to the voltage buses shown and 100 MVA .Determine the power factor at which the generator must operate.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<td>[10]</td>
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CI CCI HOD

Solutions

1)

At point A,

load is 50MW, pf = 1

so real power, $P_A = 50\,mw = \frac{50}{100} = 0.5\,pu$

$Q_A = 0$

From pt A to pt C,

48 km tr. line, calculate the reactance

$0.1 \| 0.1 + 0.1 \| 0.1$

(i) $0.05 + 0.05 = 0.1$

So $X_{AC} = 0.1$

$$I^2 X_{AC} = \frac{P^2+Q^2}{V^2} \cdot X_{AC} = \frac{0.5^2}{1^2} \times 0.1$$

$$= 0.025\,pu$$

Therefore

At pt C $P = 2 + 0.5 = 2.5\,pu$

b'coz at P there is a load of 200MW at 0.8 pf lag.

$$Q = 1.5 + 0.025$$

$$= 1.525\,pu$$

Then from C to PI E

reactance $X_{CE} = 0.4 \| 0.04 + 0.1 \| 0.6$

$= 0.02 + 0.05$

$= 0.07$

$I^2 X_{CE} = \frac{2.5^2 + 1.525^2}{1^2} \cdot 0.07$

$= 0.684$

So Generator deliver, P = 2.5 pu

Q = 1.525 + 0.6

= 2.125 pu

So p.f at which it operates is 0.76 lag

2)

Generation & Absorption of reactive power

- Synchronous generators
- Overhead lines & transformers
- Cables
- Loads

Synchronous generators

- They can be used to generate or absorb reactive power
- The ability to supply reactive power is determined by the short circuit ratio (1/synchronous reactance)
- An over excited machine generates reactive power while under excited machine absorbs it
- Generator is the main source of supply to the system of both positive & negative vars

Over head lines and transformers

Transmission lines

- Tr.lines absorbs reactive power when it is fully loaded

Let the line has I amperes and reactance per phase is X,then the vars absorbed will be I2X per phase

- On light loads ,shunt capacitance of longer lines are predominant and the lines become var generators

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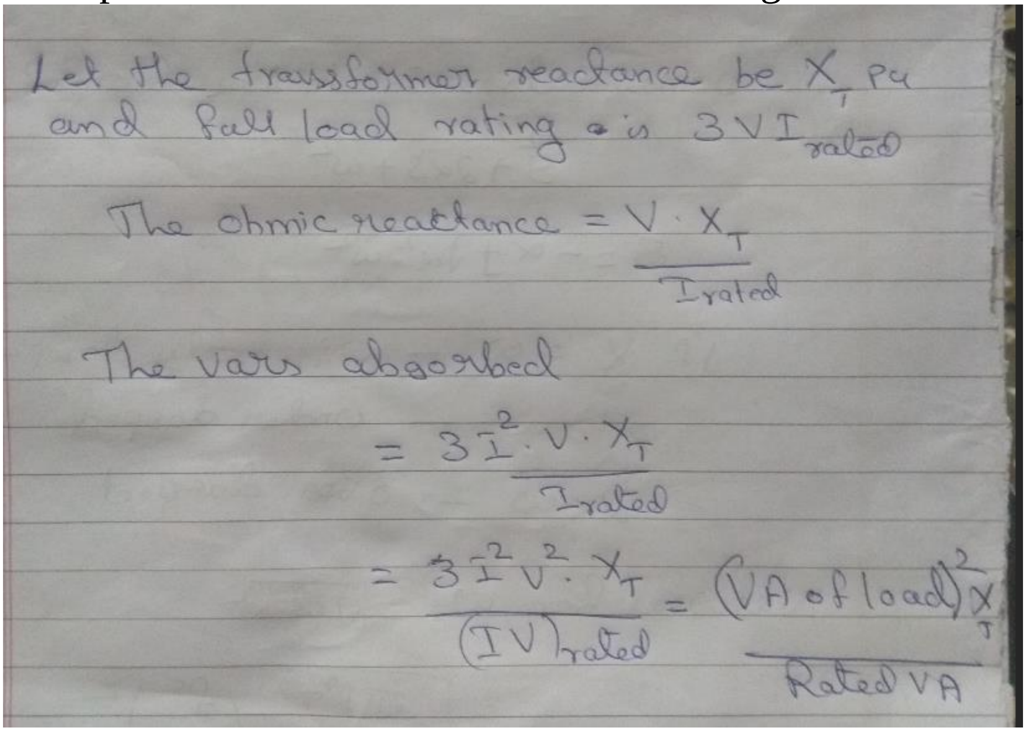


Let the transformer reactance be X_T pu and full load rating is $3VI_{rated}$

The ohmic reactance $= \frac{V \cdot X_T}{I_{rated}}$

The vars absorbed

$$= \frac{3I^2 \cdot V \cdot X_T}{I_{rated}}$$

$$= \frac{3I^2 V^2 \cdot X_T}{(IV)_{rated}} = \frac{(VA\ of\ load)^2 X_T}{Rated\ VA}$$

Cables

Cables are generators of reactive power due to shunt capacitance

275 kV,240MVA cable produce 6.25 -7.5 MVAr per km

132 kV ,produce 1.9 MVAr per km

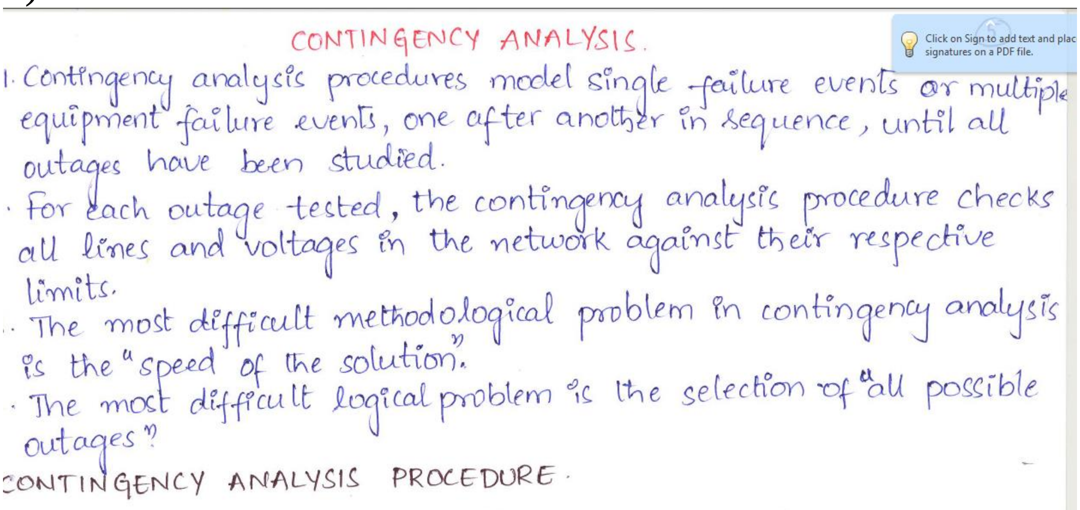
33 kV ,produce 0.125 MVAr per km

Loads

A load at 0.95 pf implies a reactive power demand of 0.33kVar

During planning a network it is desired to assess the reactive power requirements to ascertain whether generators are able to operate at the required pfs for the extreme of load to be expected

3)

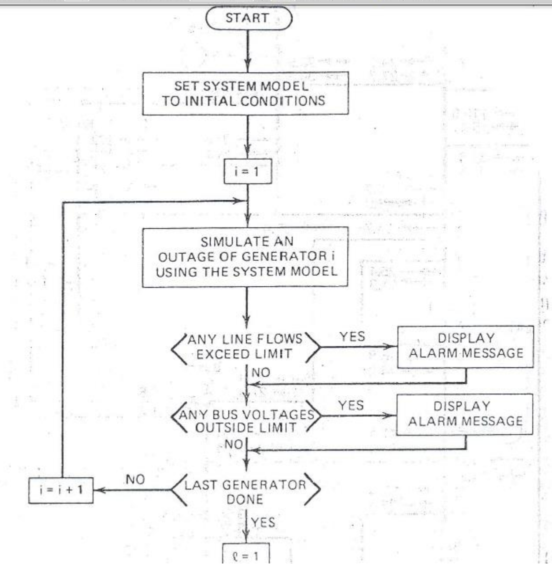


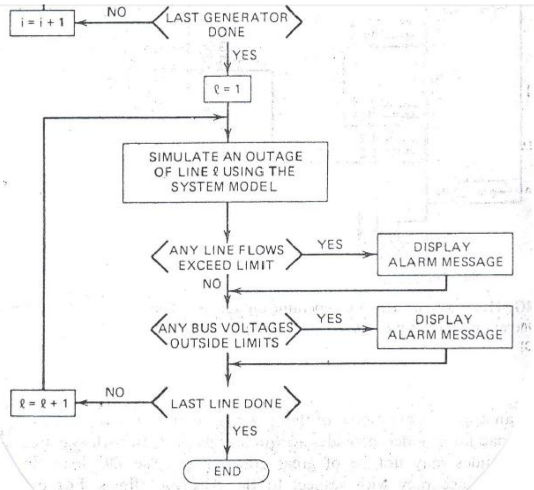
CONTINGENCY ANALYSIS.

1. Contingency analysis procedures model single failure events or multiple equipment failure events, one after another in sequence, until all outages have been studied.

- For each outage tested, the contingency analysis procedure checks all lines and voltages in the network against their respective limits.
- The most difficult methodological problem in contingency analysis is the "speed of the solution".
- The most difficult logical problem is the selection of "all possible outages".

CONTINGENCY ANALYSIS PROCEDURE.





[redacted] Contingency analysis procedure.

1. If each outage case studied were to solve in one second and several thousand outages were of concern, it would take close to one hour before all cases could be reported.
2. This would be useful if the system conditions did not change over that period of time. However power systems are prone to constant changes
3. One way to gain speed of solution in a contingency analysis procedure is to use an approximate model of power system, rather than considering exact model.
4. Linear sensitivity factors, which just consider DC flow can develop approximate model of power system.

4)

LINEAR SENSITIVITY FACTORS.

The problem of studying thousands of possible outages becomes very difficult to solve, if it is required to get the results quickly. The best way to provide a quick calculation of possible overloads is to use linear sensitivity factors.

These factors show the approximate change in line flows for changes in generation on the network. We have two types of linear sensitivity factors.

- Generation shift factors
- Line outage distribution factors.

GENERATION SHIFT FACTORS :

The generation shift factors are defined and designated as:

$$a_{li} = \frac{\Delta f_l}{\Delta P_i} \quad \text{——— (1).}$$

where l = line index

i = bus index

Δf_l = change in megawatt power flow on line 'l' when a change in generation, ΔP_i, occurs at bus 'i'.

ΔP_i = change in generation at bus 'i'.

The a_{li} factor represents the sensitivity of the flow on line 'l' to a change in generation at bus 'i'.

The new power flow on each line in the network could be calculated using a precalculated set of "a" factors. as follows

$$\bar{f}_l = f_l^0 + a_{li}\Delta P_i \quad \text{for } l = 1 \ldots L \quad \text{——— (2)}$$

where $\bar{f}_l$ = flow on line 'l' after the generator on bus 'i' fails.

f_l^0 = flow before the failure.

The outage flow $\bar{f}_l$ on each line to its limit and those exceeding their limit, will be flagged for alarming. This would tell the operations personnel that loss of generator on bus "i" would result in an overload on line.

The generation shift factors are linear estimates of the change in flow with a change in power at a bus. But the loss of generator on bus 'i' will be compensated by the machines throughout the interconnected system. Here it is assumed that the remaining generators pickup the load in proportion to their maximum MW rating. This leads to a new factor called Proportionality factor which is given by

$$\gamma_{ji} = \frac{P_j^{max}}{\sum\limits_{\substack{k \\ j,k \neq i}} P_k^{max}} \quad \text{——— (3).}$$

> Example: Load = 800MW
>
> Let G_1 = 200MW, G_2 = 300MW
>
> G_3 = 500MW; $\gamma = \frac{500}{200+300+500}$ ($\rightarrow G_3$ share)

where P_k^{max} = maximum MW rating for generator k.

Now eq(2) can be rewritten by considering proportionality factor in it

$$\bar{f}_l = f_l^0 + a_{li}\Delta P_i - \sum_{j \neq i} [a_{lj}\gamma_{ji}\Delta P_i] \quad \text{——— (4).}$$

Again $\bar{f}_l$ be compared to its limit and those exceeding their limit will be flagged for alarming.

LINE OUTAGE DISTRIBUTION FACTORS : (8)

The line outage distribution factors are defined and designated as :

$$d_{l,K} = \frac{\Delta f_l}{f_K^o} \quad \text{——— (5).}$$

where $d_{l,K}$ = line outage distribution factor when monitoring line 'l' after an outage on line 'K'.

Δf_l = change in MW flow on line 'l'.

f_K^o = original flow on line 'K' before it was outaged.

Now flow on line 'l' with line 'K' out can be determined using "d" factors as

$$\bar{f}_l = f_l^o + d_{l,K} f_K^o \quad \text{——— (6).}$$

where f_l^o, f_K^o = preoutage flows on lines l and K, respectively.

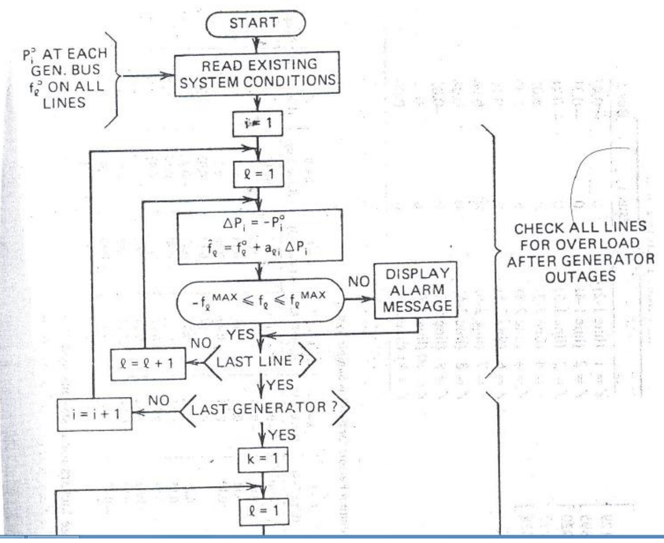
$\bar{f}_l$ = flow on line 'l' with line 'K' out.

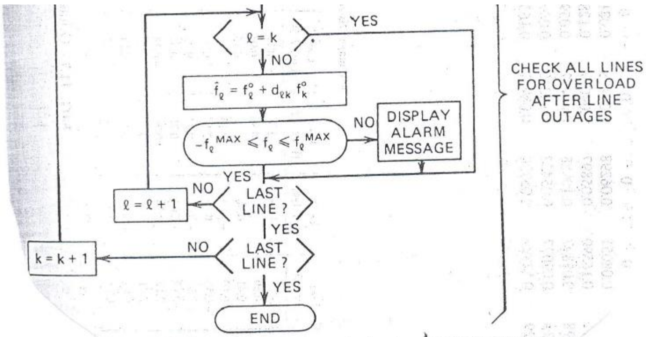
Here $\bar{f}_l$ be compared to its limit and those exceeding their limit will be flagged for alarming.

CONTINGENCY ANALYSIS PROCEDURE USING SENSITIVITY FACTORS :

1. By precalculating, the generation shift factors and the line outage
distribution factors, a very fast procedure can be setup to test all distribution factors, a very fast procedure can be setup to test all lines in the network for overload (due to generator outage or
distribution factors, a very fast procedure can be setup to test all lines in the network for overload (due to generator outage or line outage) on a particular line.

2. A line flow can be positive or negative so that we must check $\bar{f}_l$ against $-f_l^{MAX}, f_l^{MAX}$ i.e. $\boxed{-f_l^{max} \le f_l \le f_l^{MAX}}$





[redacted] Contingency analysis using sensitivity factors.

5)

Methods of reactive power Injection

- Static shunt capacitors
- Static series capacitors
- Synchronous compensators
- Current compensation by series injection

Shunt capacitors & reactors

- To maintain voltage,

Shunt capacitors are used for lagging pf

Shunt reactors are used for leading pf

- Capacitors are connected either directly to the bus bars or to the tertiary winding of a main transformer
- Switched capacitors in parallel with semiconductor-controlled reactors provide modern variable var compensators for fast control of voltages in power systems

Series capacitors

- Connected in series with the line conductors
- To reduce the inductive reactance between the supply point and load

Drawback

- High overvoltage produced when a short circuit current flows through the capacitor
- Special protective devices need to be incorporated

Merits between shunt & series capacitors

1. If the load var requirement is small , series capacitors are of little use
2. With series capacitors reduction on line current is small . Hence if thermal considerations limit the current , little advantage is obtained and shunt compensation should be used
3. If voltage drop is the limiting factor, series capacitors are effective ,voltage fluctuations due to arc furnaces etc are evened out
4. If the total line reactance is high ,series capacitors are very effective and stability is improved

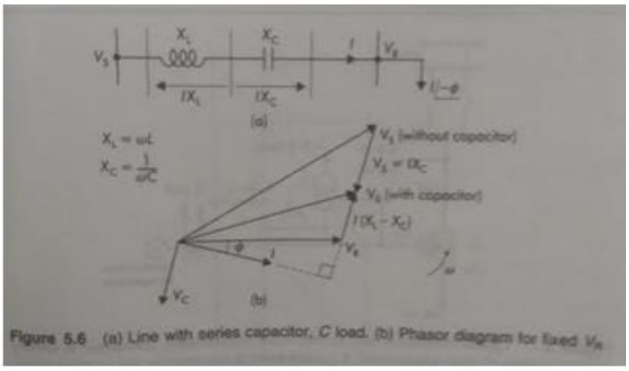
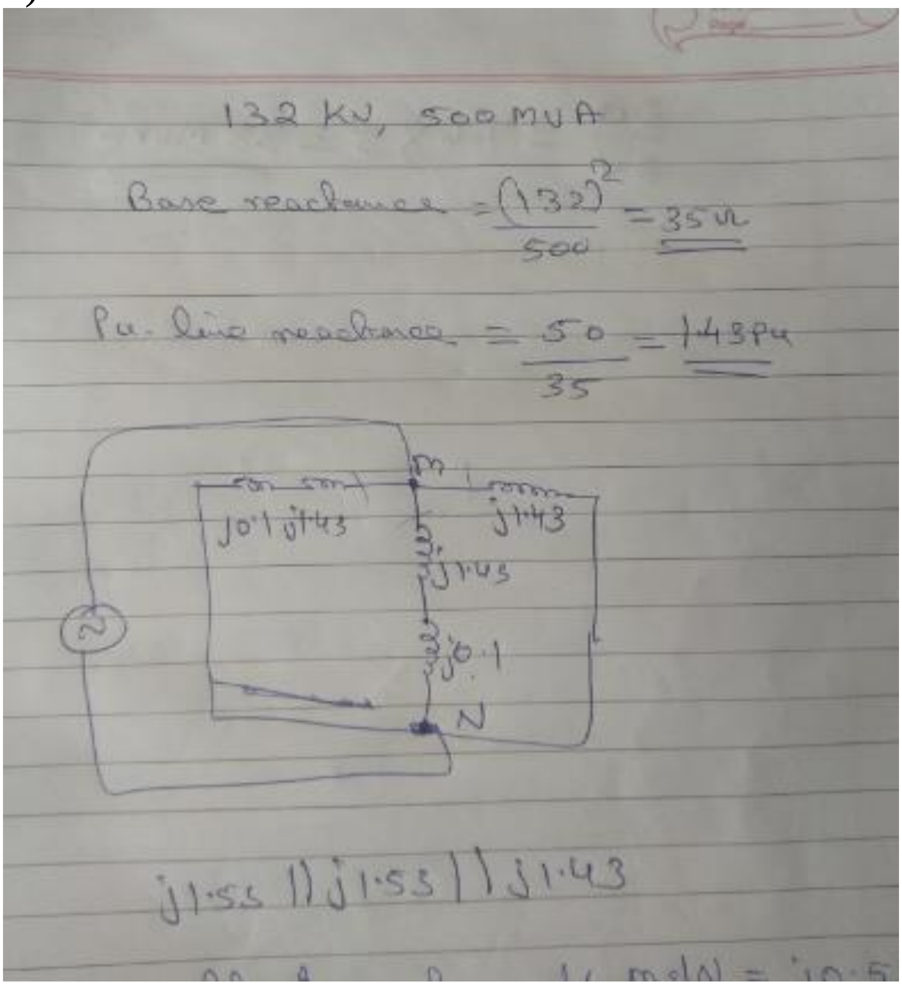


Figure 5.6 (a) Line with series capacitor, C load. (b) Phasor diagram for fixed V_R

Synchronous compensators

- Synchronous compensator is a syn.motor running without a mechanical load depending on the value of excitation , it can absorb or generate reactive power
- When used with a voltage regulator the compensator can automatically run overexcited at high load and under excited at light load.
- Great advantage is the flexibility of operation for all load conditions
- Cost of installation is high but it can be justified
- Being a rotating machine ,its stored energy is useful for riding through transient disturbances including voltage sags

6)



resultant reactance b/w m and N = $j0.5$ pu.

fault pu MVA $= \frac{1}{0.5} = 2$ pu

$= 2 \times 500 = 1000$ MVA

fault current $= \frac{1000}{\sqrt{3} \times 132} = 4380$ A at zero p.f lag.

$\frac{\partial Q}{\sqrt{3}\,\partial V} = 4380$ A.

$\frac{\partial Q}{\partial V} = 4380 \times \sqrt{3} = 7.6$ MVAr/kV

$\frac{\partial Q}{\partial V} = 7.6 \times 5 = 38$ MVAr