Example 2– Revisit Capacitor Part 1, Ex 2

A 12.47 kV wye-connected three-phase feeder serves a mix of residential and commercial load as shown below with three-phase peak loading values as follows:

Section #	Load Type	Load (kVA)	P.F. (lagging)	Line Length (miles)
0-1	Spot	2000	0.9	1.5
1-2	Spot	2000	0.9	1.5
2-3	Spot	1000	0.9	1.0
3-4	Spot	1500	0.9	2.0

The feeder consists of 336 conductors with positive sequence impedances of:

R = 0.306 Ohms/phase-miles and X = 0.630 Ohms/phase-miles.

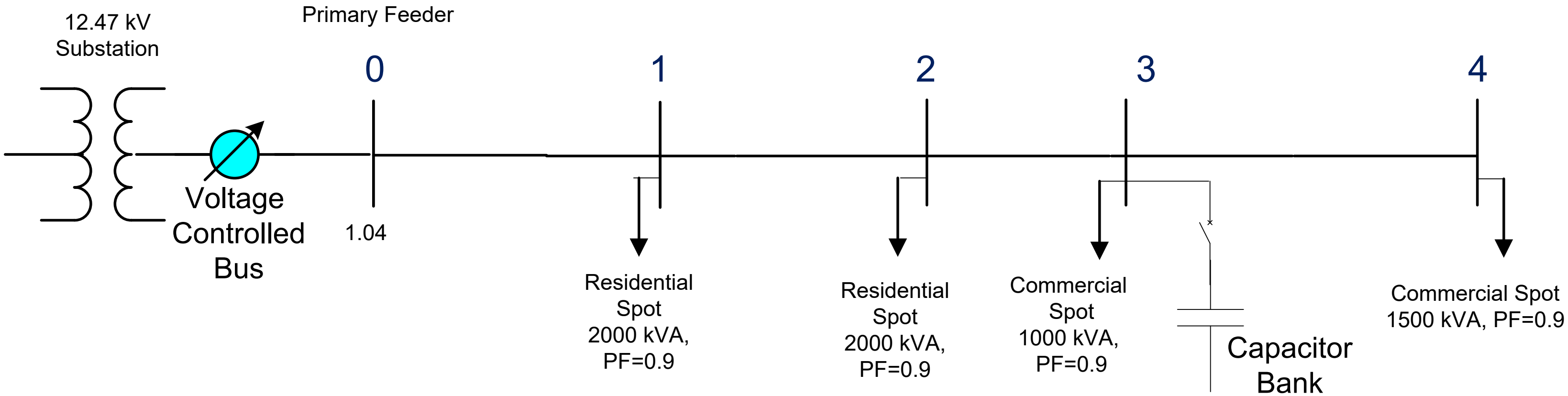
The substation voltage at Bus 0 is regulated at 1.04 p.u. Use the K factor approach to calculate the voltages requested below.

(c) Now we want to evaluate adding a Capacitor to improve the circuit using the ½ kVAR rule. Starting with no capacitor in the circuit, then add a 2700 kVAR capacitor bank to Bus 2.

i. Determine the new voltage at Bus 4.
ii. Determine the new value for circuit kW losses.

(d) Which capacitor placement gives better results in terms of reducing circuit kW losses?

Example 2 – Fixed Capacitor Bank Sizing (2)



Feeder Diagram for Capacitor Sizing Problem

Example 2 – Section Q Flows

(c) Adding cap bank using 1/2 kVAr rule.

PP9

Condition imp to 1.0 pf.

Location & size :-

Total reactive power $= 6500 * \sin(25.84) = 2833.3$ kVAr

We have 300 kVAr (3φ) cap banks.

$\Rightarrow$ number of cap banks required $= \frac{2833.3}{300} = 9.4 \sim$ "9" cap banks

$\Rightarrow$ $\frac{1}{2}$ Cap. VAr rating $= \left(\frac{1}{2} * 2700 = 1350 \text{ kVAr}\right)$

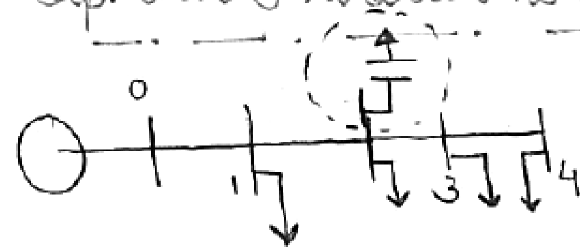
$Q_{01} = 6500 * \sin(25.84)$
$= 2833.3$ kVAr

$Q_{12} = 4500 * \sin(25.84)$
$= 1961.36$ kVAr

$Q_{23} = 2500 * \sin(25.84)$
$= 1089.65$ kVAr

$Q_{34} = 1500 * \sin(25.84)$
$= 653.8$ kVAr

Thus based on the data obtained The best location for the Cap. bank location is bus 2.



Example 2 - ½ kVAR Rule – Voltage Drops

$$\Delta VD_{01} = 1.5\left[-4.051 * 10^{-4}\right] * 2700 = -1.64 \text{ percent } (\%)$$

$$\Delta VD_{12}^{cap} = 1.5\left[-4.051 * 10^{-4}\right] * 2700 = -1.64\ \%$$

$$\Rightarrow V_4 = 1.04 - \left(\frac{7.785}{100}\right) + \left(\frac{1.64}{100}\right) * 2 = \underline{0.995 \text{ per unit}}$$

(or 7164 volts)

$$Q_{01} = (2833.3 - 2700)\ \text{kVAr} = 133.3\ \text{kVAr}$$

$$P_{01} = 6500 * \cos(25.84) = 5850.09\ \text{kW}$$

$$\Rightarrow \text{new } S_{01} = 5851.6\angle 1.30 \Rightarrow \cos(1.3^\circ) = 0.999$$

Thus, its also clear that addition of kVAr's via capbank improves the top of feeder power factor.

Example 2 - ½ kVAR Rule – Current Flows and Losses

improves the drop of feeder power factor.

ii) $$|I_{01}| = \frac{\sqrt{(6500*0.9)^2 + (2833-2700)^2}}{\sqrt{3}*12.47} = 270.92 \text{ Amps.}$$

$$|I_{12}| = \frac{\sqrt{(4500*0.9)^2 + (1961-2700)^2}}{\sqrt{3}*12.47} = 190.61 \text{ Amps.}$$

$$\left.|I_{23}| = 115.75 \text{ Amps} \ \& \ |I_{34}| = 69.45 \text{ Amps}\right] \text{previously calculated.}$$

$$P_{Loss} = 3*(270.92)^2*(0.306*1.5) + 3*(190.6)^2(0.306*1.5)$$
$$+ 3*(115.75)^2*(0.306) + 3*(69.45)^2*(0.306*2) \text{ pp10}$$
$$= \left[(101.1)+(50.03)+(12.3)+(8.86)\right] \text{ kWatts}$$
$$= 172.3 \text{ kWatts}$$

Example 2 - ½ kVAR Rule - Comparison

(d)

- Comparing two results we can see that losses are nearly same.
  But number of capacitors required in part 'b' is less than part 'c'.
- Normally we see lower losses when we use 1/2 kVAr rule but in system under consideration we can observe that the Q injection is improving voltage profile of bus 1 & 2. as these buses are loaded more.
- Cap. bank placement at bus 2 or bus 3 is ~~was~~ causing similar effects in the voltage profile and losses.