I. Determination of Load-Model Parameters.

Theory is easy
Practice is difficult.
A. Measurement-based approach

bulk level @ substitution level

ref. 3
\[ P = P_0 \left[ \rho \bar{U}^2 + \rho_2 \bar{V} + \rho_3 \right] \left[ 1 + k_{\text{eff}} \right] \]
steady state

\[ \frac{dP}{dv} \]

(+) \quad \frac{dQ}{dv}

(-) \quad \frac{dQ}{dv}

(=) \quad \text{freq.}
B. Component-based approach

P. 309
Reactive Power & Voltage Control

I. System Requirement
   a) \( V_{	ext{min}} \leq V \leq V_{	ext{max}} \)
   b) enhance transient stability

Diagram:
- \( P_m \)
- \( E \) and \( q \) nodes
- \( V_s \) and \( V_R \) nodes
c) minimize $I^2R$ losses

Supply vars where consumed

$$P = 3 \frac{|V_s||K_r| \sin \theta}{X}$$
II. Comparison to Freq. Control

Voltage Control is mostly affected by local balance of Q supply and Q absorbed.
The overall system $E P = 0$ depends on $E$ and $P$. 

*versus*

The overall system $E P = 0$ depends on $E$ and $P$. 

*versus*
\[
\frac{\text{limits}}{|I + \delta|} \text{ end region heating}
\]
(-) not controllable
independent of load

transformers absorb Q
\( Q \) 

normally 

\( b \)
Overhead lines

Supply or absorber 6 Ω

lightly loaded

highly loaded

\[ \frac{\text{Tur}}{\text{Vn}} \]
Compensating devices

Shunt reactor

Use for light load conditions

Limit voltage rise
Short capacitor

- Boost voltage
  (+) low cost
  (-) $Q \propto V^2$
\[ \frac{x^2 - x^4}{\sqrt{1 - |x|}} = \frac{1}{3} |x| \ln |x| + \text{c.c.} \]
\[ \text{synchronous resonance} \]

\[ \text{SSR} \]

\[ \text{(+) and (-)} \]
synchronous condensers

(+) supply or consume Q continuously, variable
Q dependent if not U of system
Kinetic energy storage \( \Rightarrow P \)
(\(\text{flywheel}\))
\(-\) $\uparrow$

\(5/10 \rightarrow \text{w/ } P=0 \rightarrow \text{System}\)

\[\times\]

PM

\(P \text{ small}\)
Static Var Systems SVC

versus rotating SVC compensators

e.g. TCR Thyristor - ctrl'd reacto
TSC Thyristor switched capacitor
Ideal static system

\[ p = 0 \]

\[-\infty < q < +\infty\]

instantaneous response