Synchronization

- Detect zero crossing of input fundamental frequency waveform
  - Possibly delay by 90 degree to get peak
  - Proper delay requires knowledge of actual system frequency (not the ideal value)
  - Inputs include phase error (from measuring circuit and system drift), and base frequency
- Note use of “analog” signals, could do this digitally as well

- The modulating signal is synchronized with to the phase voltage or line current
- A fairly simple approach is to use the zero crossings.
- Need accurate detection of zero crossing and determination of frequency
- Free of distortion
Phase Locked Loops

- Several common schemes used in grid connected converters
  » Custom development each manufacturer
- Phase-locked oscillator developed for HVDC--John Ainsworth.
  » Trade secret
- Implementation needed in simulation

ATPDraw Implementation: Simple Zero Crossing Based: Three Phase
Phase Locked Loop

- Integrator resets every $2\pi$ radians

Phase Error $\rightarrow \frac{1}{sT_1} \rightarrow \frac{1}{s} \rightarrow \omega_r t = \theta_r$

Ramp from 0 to $2\pi$

Can add phase correction

Phase Correction Approach

- Create an orthogonal pair of vectors
  » Park’s transformation if three phase measurement
  » Phase rotation (delay) if single phase input
- Need instantaneous angle reference ($\omega_r t = \theta_r$)
- Phase Error = $-V_d \sin(\theta_r) + V_q \cos(\theta_r)$
ATPDraw Implementation: Power System Model

TACS Control for Voltage Sources

Synchronization

ATPDraw Implementation: Phase Locked Loop: Phase A

Phase Lock Loop

Synchronization
PERR and THETAR with phase jump due to load change

PERR and THETAR with sustained SLG Fault
Results with PLL--SLG Fault

Kp=100, Ti=8.3E-3

Kp=1000, Ti=8.3E-4

Results with PLL--Three Phase Fault

Kp=100, Ti=8.3E-3

Kp=1000, Ti=8.3E-4
Compare $\omega t$ with PLL THETAR (phase jump case)

RAMP.pl: RAMPA
pllcase.pl: THETAR
factors: 57.3
offsets: 0

Compare $\omega t$ with PLL THETAR (SLG fault case)

RAMP.pl: RAMPA
pllcase.pl: THETAR
factors: 57.3
offsets: 0