GENQEJ

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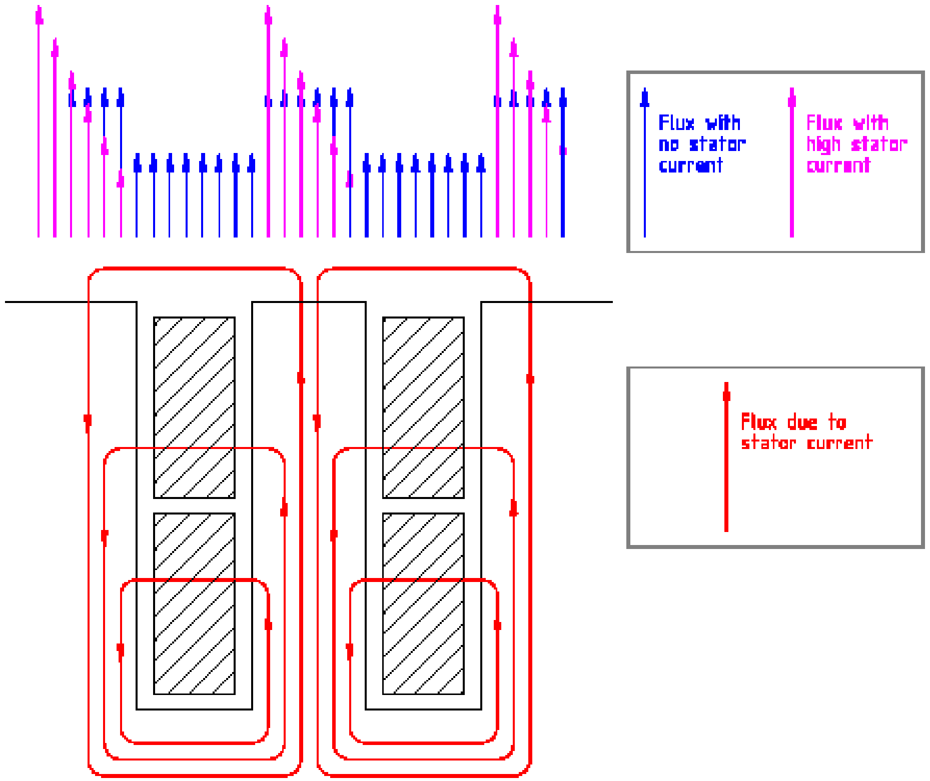
History

- June 14, 2003 – a 38-second multi-phase fault at Hassayampa 500-kV substation, significantly depressed voltages in Phoenix area, OEL operation at Palo Verde generators
  - Model validation studies were performed using PMU data recordings from Palo Verde substation
  - Palo Verde models were boosting a few hundred more MVARs than actual units based on PMU records
- 2004 – US Army, BPA and John Undrill tested John Day generators
  - GENSAL model over-estimated the generator reactive capability by about 50%
- Shawn Patterson at USBR made similar observations during his model validation tests

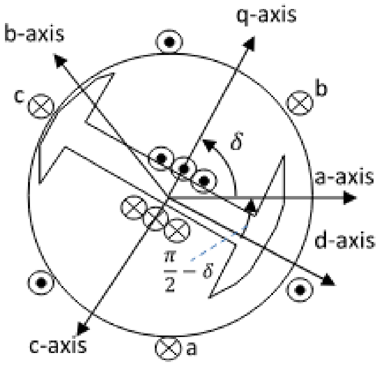
- WECC MVWG actions
  - Retire GENSAL models
  - Need to account for saturation effects introduced by high stator current
  - Introduce GENTPJ model
  - GENQEC model introduced

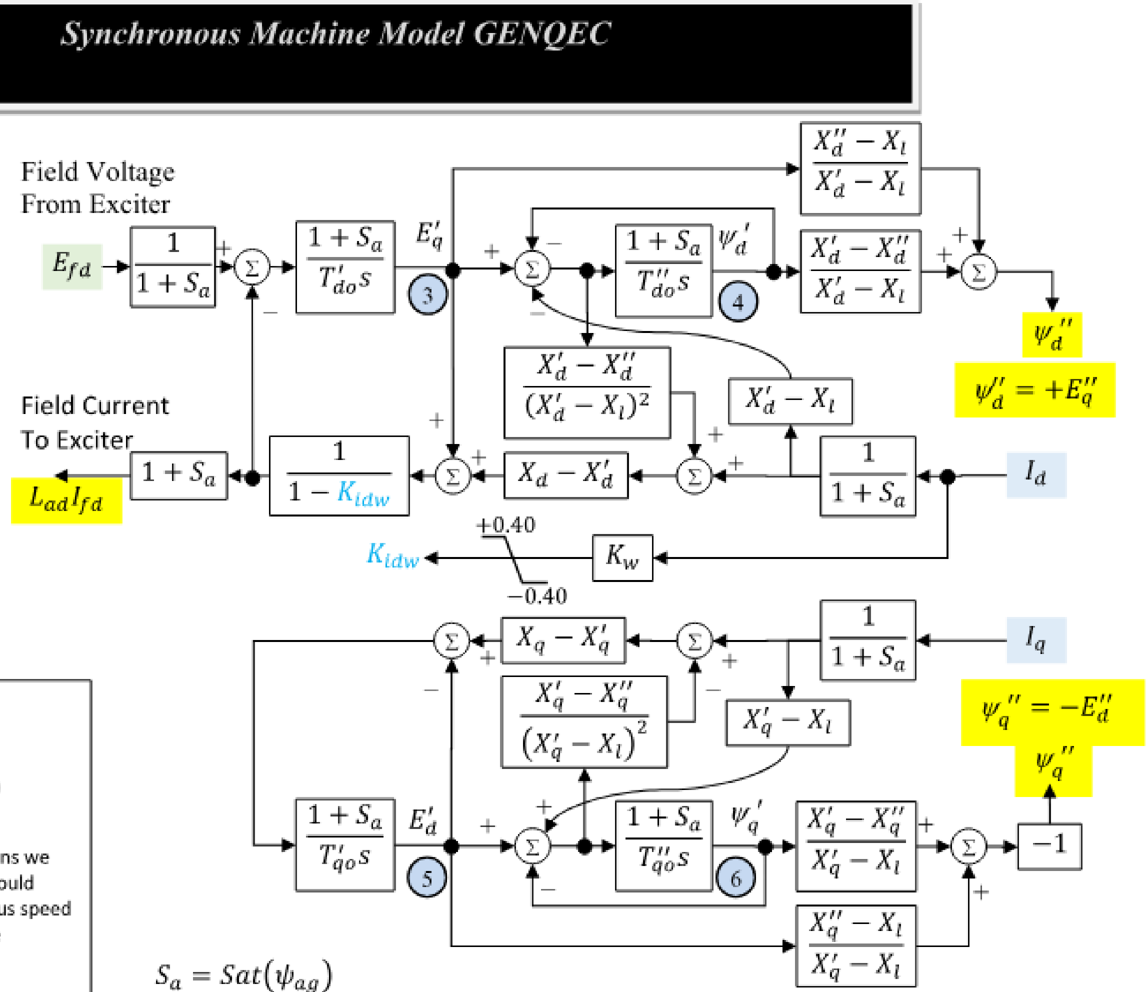


Stator current distorts the flux distribution in many parts of the machine. For example, in this illustration the flux profile across the center tooth is uniform when there is no stator current (blue) and is distorted when stator current is present (magenta).   Stator current increases the degree to which saturation affects the flux crossing the air gap.

GENQEC makes an approximate treatment of saturation using the compensation factor kw as shown.

Machine Model GENQEC





Mechanical Swing Equations

(1) $\dot{\delta} = \omega * \omega_0$

(2) $\dot{\omega} = \frac{1}{2H}\left(\frac{P_{mech} - D\omega}{1+\omega} - T_{elec}\right)$

$\omega =$ per unit speed deviation, so $\omega = 0$ means we are at synchronous speed and $\omega = 1$ would mean it's spinning at double synchronous speed

$\omega_0 =$ synchronous speed $2\pi f_0$ where f_0 is the nominal system frequency in Hz

Note: If option *Ignore Speed Effects in Generator Swing Equation* is true, then instead use

$$\dot{\omega} = \frac{1}{2H}\left(P_{mech} - D\omega - T_{elec}\right)$$

$$S_a = Sat(\psi_{ag})$$

$$\psi_{ag} = \frac{1}{1+\omega}\sqrt{(V_{qag})^2 + (V_{dag})^2} = \frac{1}{1+\omega}\sqrt{(V_{iag})^2 + (V_{rag})^2}$$

$$V_{qag} = V_{qterm} + I_q R_a + I_d X_l$$

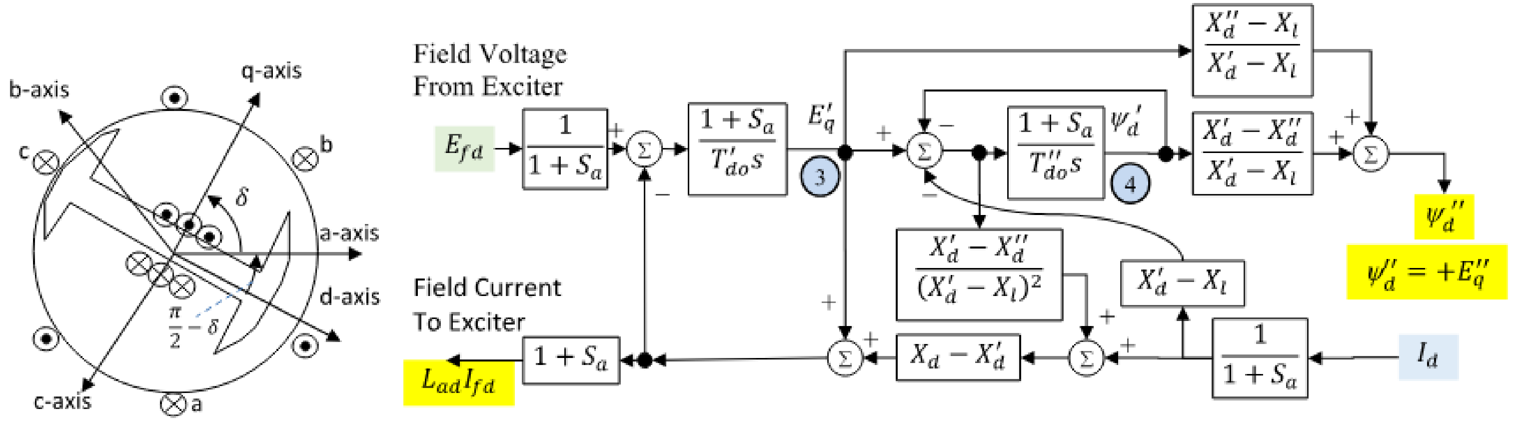
$$V_{dag} = V_{dterm} + I_d R_a - I_q X_l$$

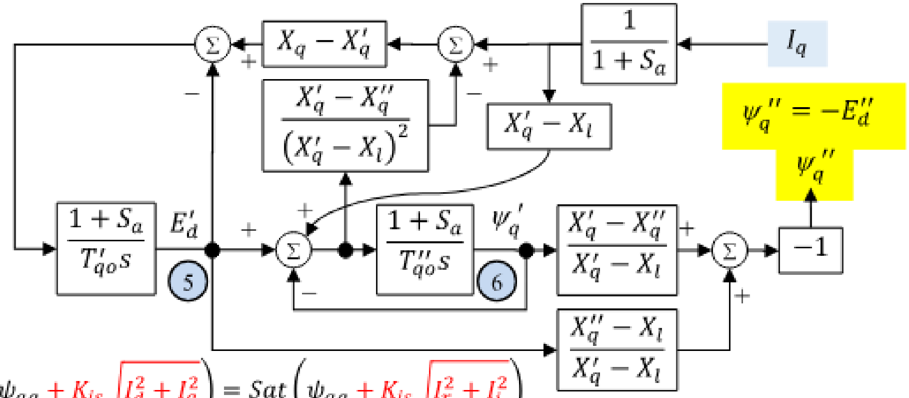
https://www.powerworld.com/WebHelp/Default.htm#TransientModels_HTML/Machine%20Model%20GENQEC.htm

GENQEJ makes a different approximation of saturation effects using Kis.

Machine Model GENQEJ

Synchronous Machine Model GENQEJ





Mechanical Swing Equations

(1) $\dot{\delta} = \omega * \omega_0$

(2) $\dot{\omega} = \frac{1}{2H}\left(\frac{P_{mech} - D\omega}{1+\omega} - T_{elec}\right)$

$\omega =$ per unit speed deviation, so $\omega = 0$ means we are at synchronous speed and $\omega = 1$ would mean it's spinning at double synchronous speed

$\omega_0 =$ synchronous speed $2\pi f_0$ where f_0 is the nominal system frequency in Hz

Note: If option *Ignore Speed Effects in Generator Swing Equation* is true, then instead use

$$\dot{\omega} = \frac{1}{2H}(P_{mech} - D\omega - T_{elec})$$

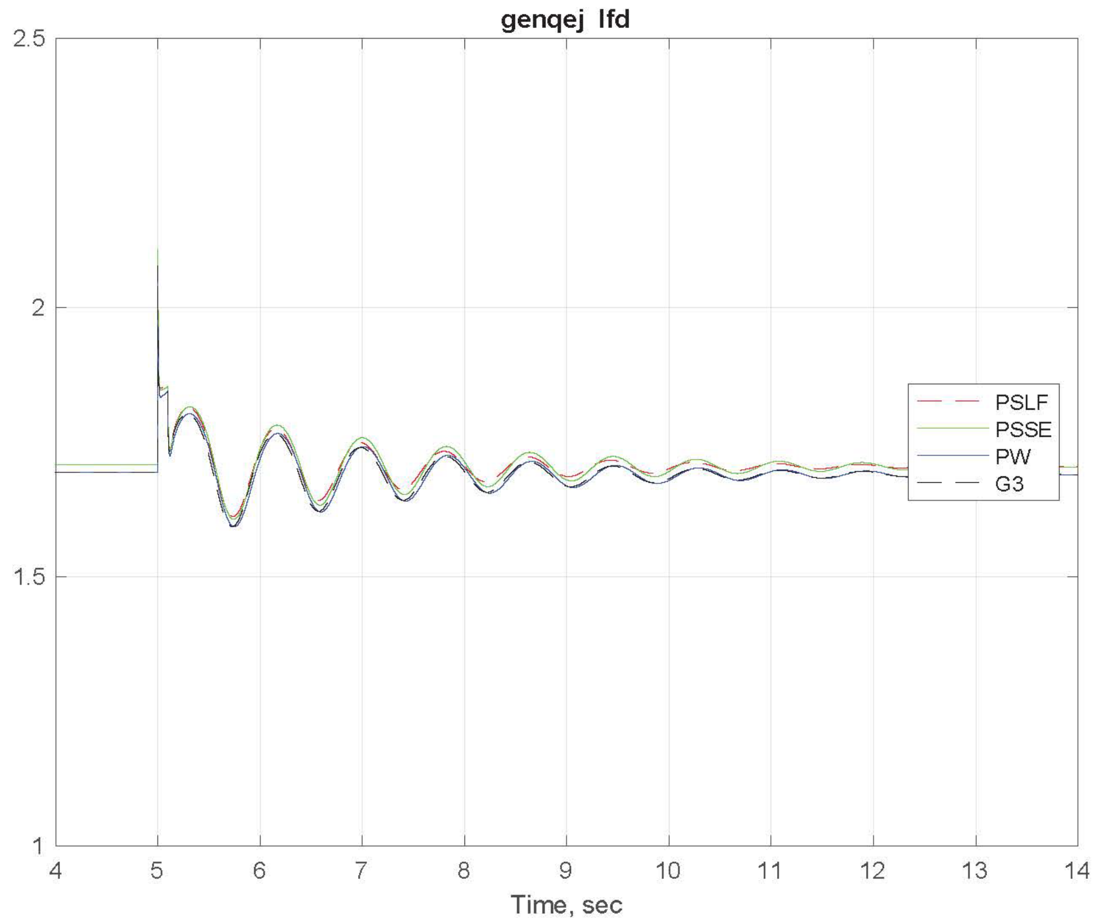
$$S_a = Sat\left(\psi_{ag} + K_{is}\sqrt{I_d^2 + I_q^2}\right) = Sat\left(\psi_{ag} + K_{is}\sqrt{I_r^2 + I_i^2}\right)$$

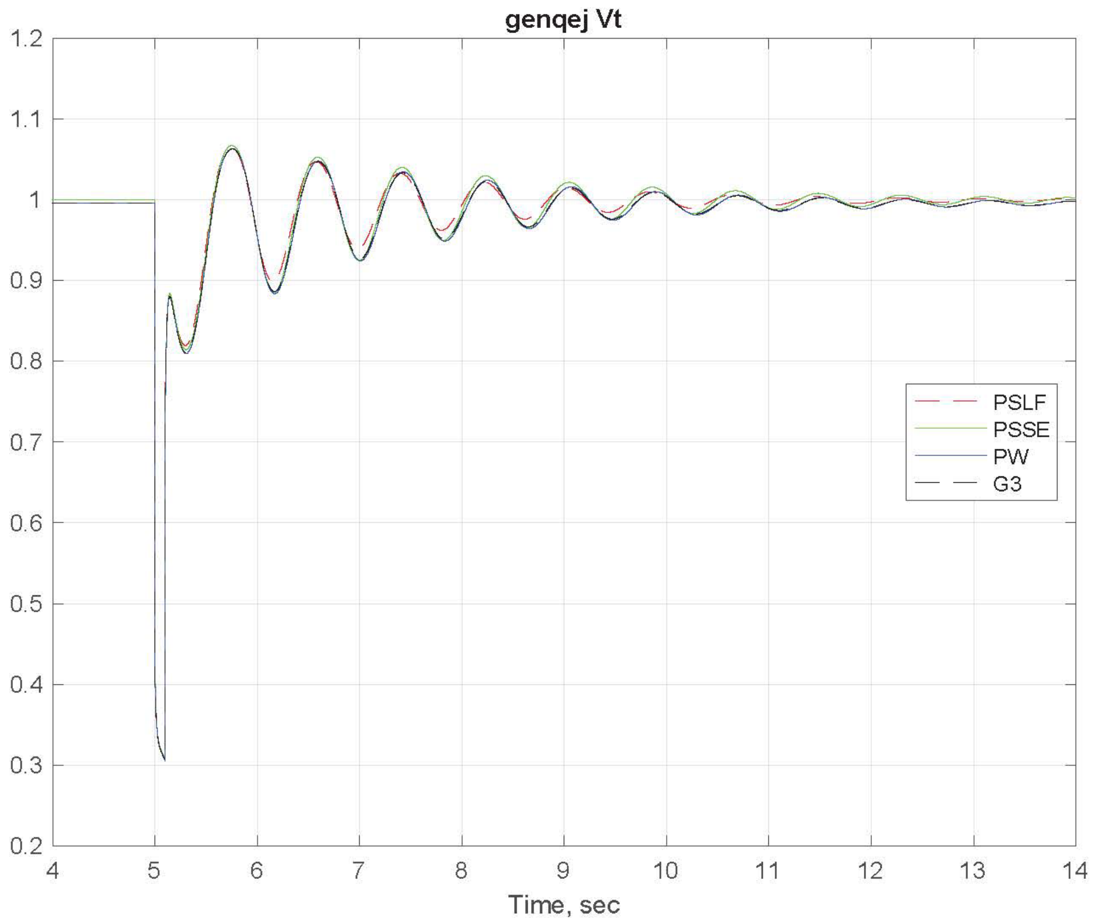
$$\psi_{ag} = \frac{1}{1+\omega}\sqrt{\left(V_{qag}\right)^2 + \left(V_{dag}\right)^2} = \frac{1}{1+\omega}\sqrt{\left(V_{iag}\right)^2 + \left(V_{rag}\right)^2}$$

$$V_{qag} = V_{qterm} + I_q R_a + I_d X_l$$

$$V_{dag} = V_{dterm} + I_d R_a - I_q X_l$$

https://www.powerworld.com/WebHelp/Default.htm#TransientModels_HTML/Machine%20Model%20GENQEJ.htm

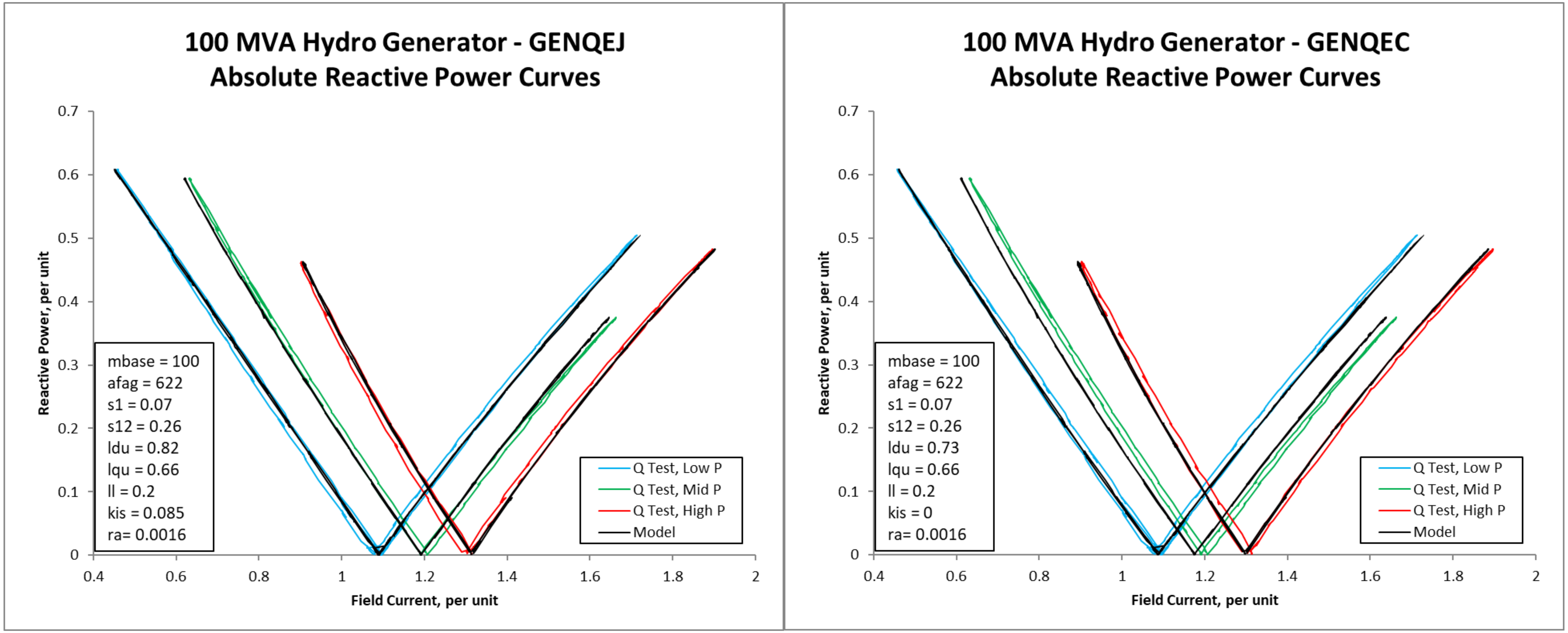


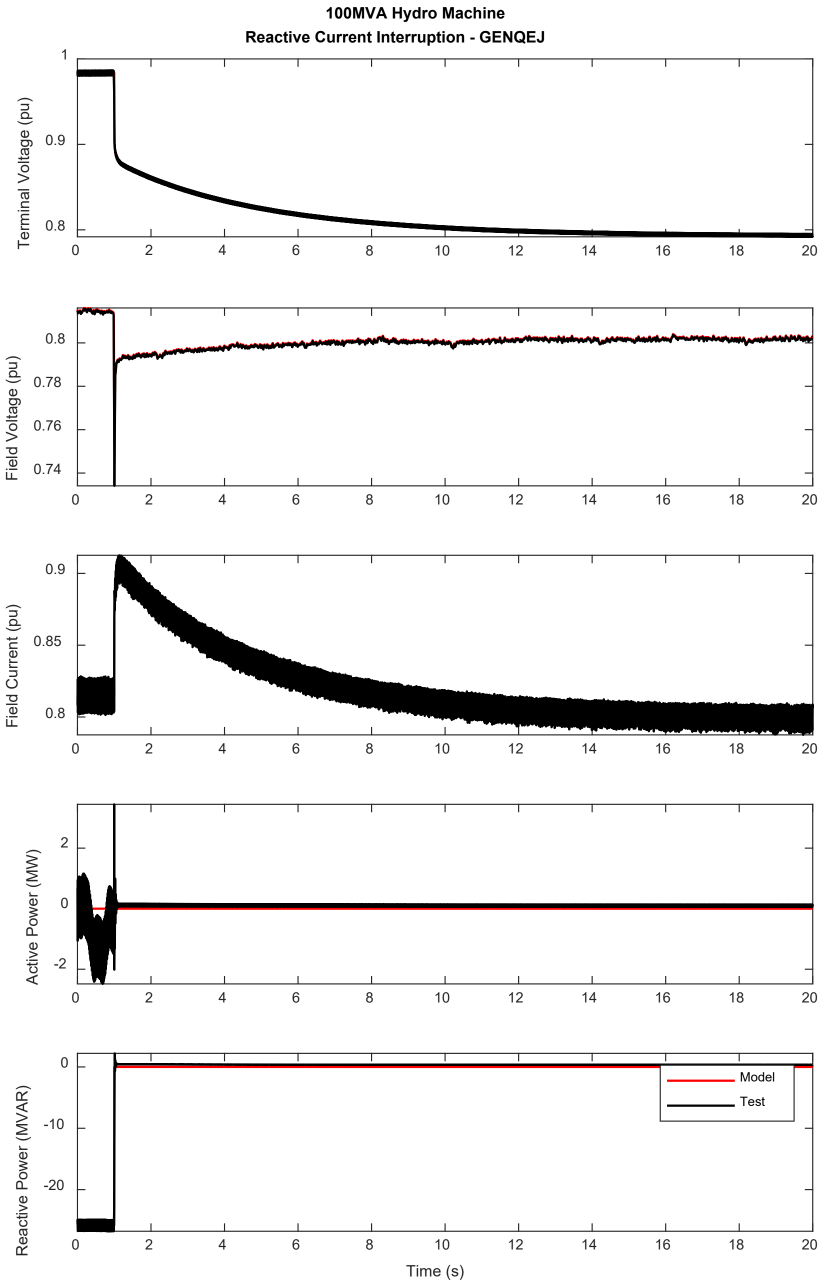


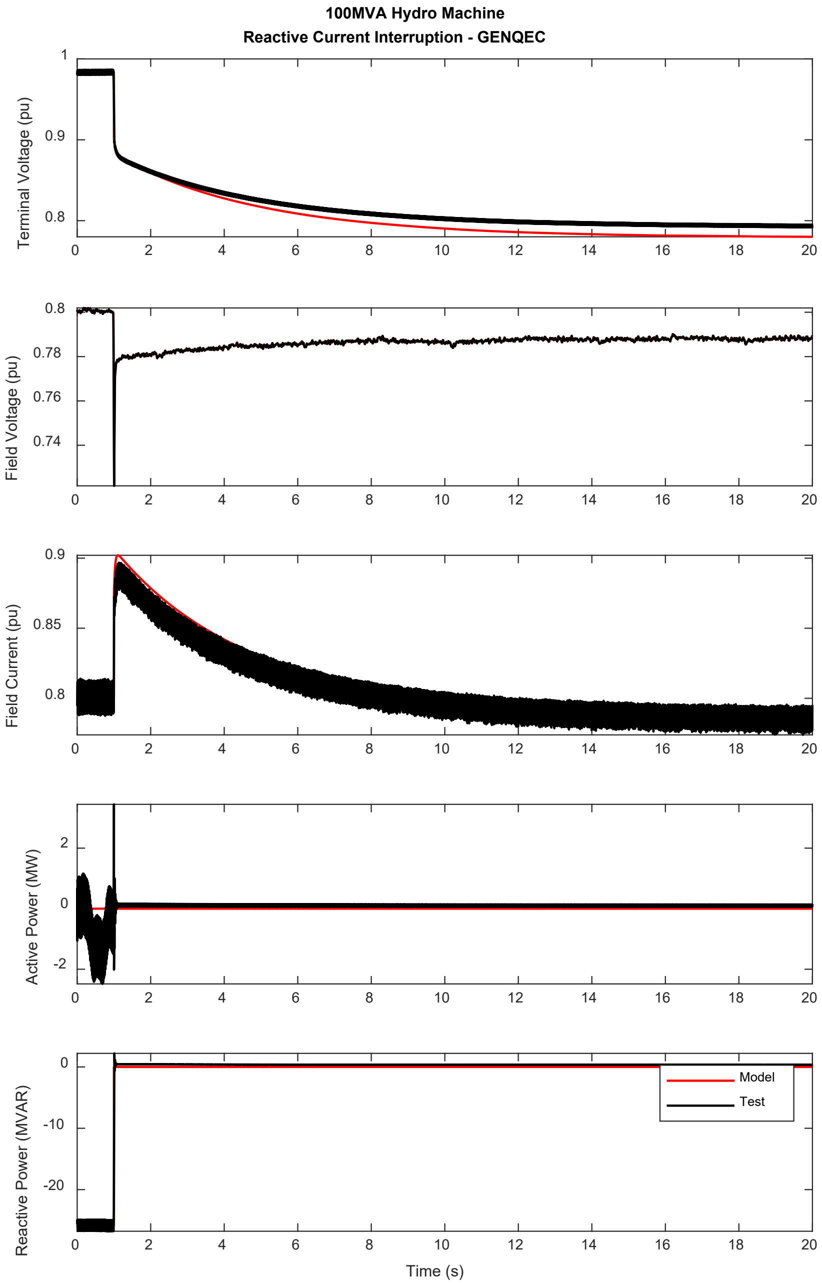
PSLF, PSSE, and Power World have all implemented the model and made it available in the current version. They have been baseline tested to confirm the implementations are consistent.

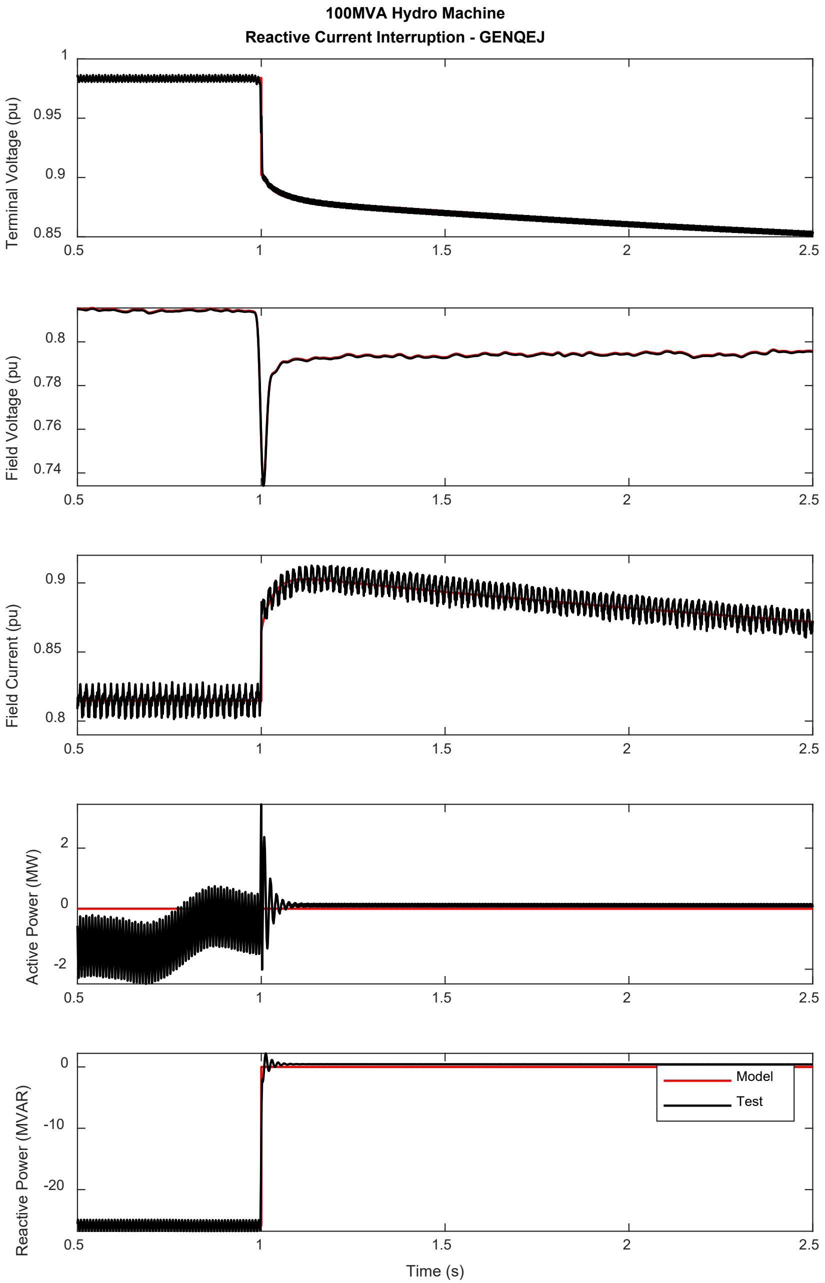
The figures below show a typical example of a hydro machine that is better fit by GENQEJ.

One method of finding Kis is to minimize error between the measured and modeled field current using several reactive power curves at near zero load, mid load, and high load.




100MVA Hydro Machine
Reactive Current Interruption - GENQEJ
Terminal Voltage (pu)
Field Voltage (pu)
Field Current (pu)
Active Power (MW)
Reactive Power (MVAR)
Model
Test
Time (s)


100MVA Hydro Machine
Reactive Current Interruption - GENQEC
Terminal Voltage (pu)
Field Voltage (pu)
Field Current (pu)
Active Power (MW)
Reactive Power (MVAR)
Model
Test
Time (s)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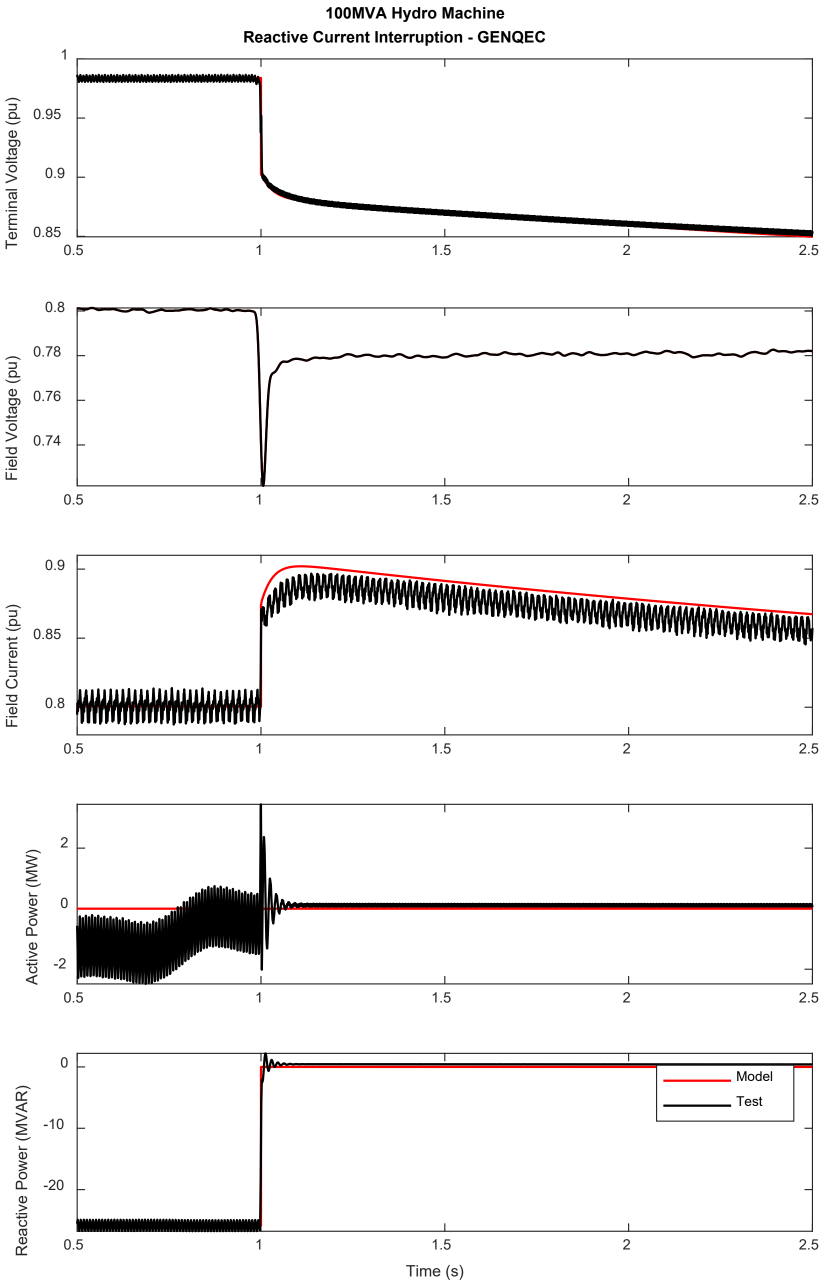
100MVA Hydro Machine
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Terminal Voltage (pu)
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Time (s)

Conclusion

- GENQEJ provides an alternative model that improves the steady state and dynamic simulations in comparison with recorded data for some machines.