Application: Modal Analysis of Electrical Power Systems

The QR Algorithm plays a pivotal role in model analysis of electrical power systems, which examines the small-signal stability of large, interconnected grids. With the help of QR algorithm engineers can construct the state matrix of the linearized power-system model (often derived from differential-algebraic equations describing generator dynamics and network interactions). And the eigenvalues we get of this matrix reveal whether oscillations in voltage or rotor angle will decay or grow over time, indicating system stability.

In the study paper "QR Algorithm: 50 years later," by Tam (2010), the QR algorithm efficiently computes all eigenvalues of a real matrix through iterative orthogonal transformations, preserving numerical stability and minimizing round-off errors. This is crucial in power-system modeling, where large sparse matrices sometimes 10000 x 10000 must be analyzed to monitor interarea oscillations. And then in the study report "The QR Algorithm Revisited," by Francis (2010), emphasizes how the QR decomposition provides a robust framework for iterative convergence toward upper-triangular form, making it one of the most dependable tools for eigenvalue extraction in engineering computations.
In model analysis, each eigenvalue's real part determines the damping of an oscillation mode, while the imaginary part corresponds to its natural frequency. For example, a complex conjugate pair with small negative real parts indicates lightly damped oscillations that could lead to instability if system parameters change. By using the QR algorithm to compute these eigenvalues, engineers can identify critical modes and design stabilizing controllers such as Power System Stabilizers (PSS) or Flexible AC Transmission System (FACTS) devices. The QR algorithm forms the computational backbone of dynamic-stability software used by utilities worldwide.
In the context of power-system modal analysis:

- Negative real parts → Stable, well-damped oscillations.
- Zero or positive real parts → Unstable or sustained oscillations.
- Magnitude of the imaginary part → Frequency (Hz) of the oscillatory mode.

Performing the QR algorithm allows engineers to predict, interpret, and control the dynamic response of complex power networks.
References

1. Tam, P. (2010). *QR Algorithm: 50 Years Later*. Duke University.
   https://people.duke.edu/~hpgavin/SystemID/References/Tam-QR-history-2010.pdf
2. Francis, J. G. F. (2010). *The QR Algorithm Revisited*. University of California, Berkeley, EECS Department, Technical Report
   http://eecs.berkeley.edu/Pubs/TechRpts/2010/EECS-2010-131.pdf
3. (AI Prompt Used) "Explain an application of the QR Algorithm in Electrical Engineering." - ChatGPT (GPT-5, 2025).