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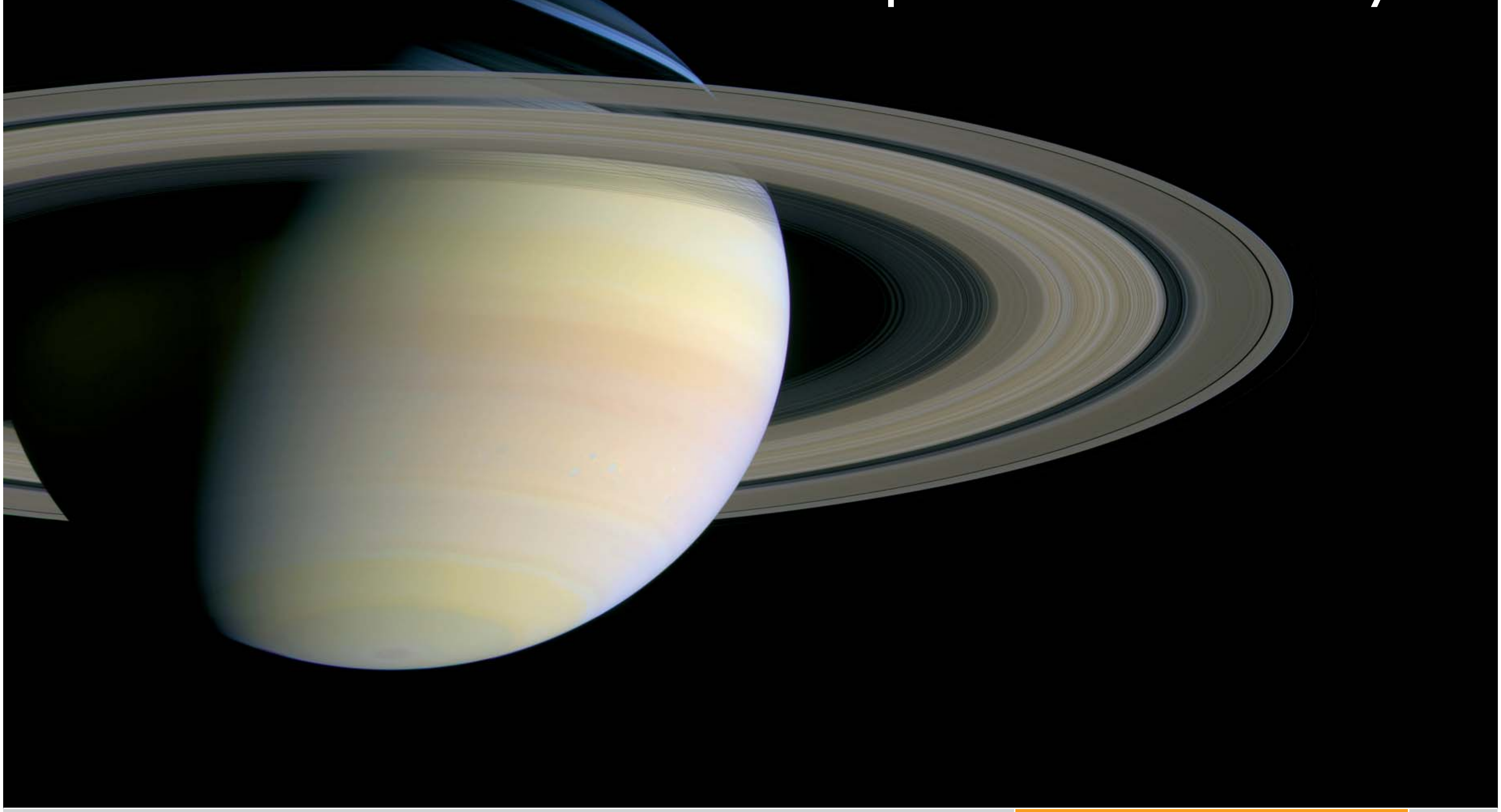
Get time to react.

CPR-D Collapse Prediction Relay



CPR-D Collapse Prediction Relay

Chaos and Order

Chaos and order are often neigbouring closely side by side and also undergo transitions into each other. The divisions and gaps within the Saturn rings indicate, that also in classical physical systems stable and regular trajectories are the exception.

An example: the 2nd-largest gap within the Saturn rings ("Encke-gap") is a region, where actually no stable orbit of celestial bodies should be possible. Yet, next to and inmidst of this region there do exist stability zones. Hence the little moon Pan in the Encke gap exhibits a stable orbital trajectory around Saturn.

Order and chaos are closely lying side by side in electrical power systems too, as it was demonstrated in the collapses (blackouts) in USA and Europe during the year 2003.

Blackouts are Expensive

Due to the total electrical power blackout in Midwest and Northeast United States and Ontario, Canada at August 2003, nearly a fourth of the whole electrical power grid of the USA was shut down. The outage affected an area with an estimated 50 million people. Estimates of total costs range up to 6 billion US-$. In the US there is a blackout with 500.000 people affected at every 4 months (J. Apt, Carnegie-Mellon-University). Consequence: Tremendous cost and financial loss are resulting in more and more expensive subsequent investments.

Blackouts can be Avoided

Nowadays, electrical power systems experience an increasing vulnerability due to economical and ecological demands, whose realization drives the systems to their physical limits. Simultaneously, the load characteristics are in change.
In this situation, for instance during power line tripping, the power system can easily exhibit a dynamic behaviour, which comes up with superimposed oscillations at special frequencies.
This system dynamics may lead to a collapse, when a "critical point", called Hopf-point, has been passed by.

Blackouts, like those in New York and other collapse events in electrical power systems can comprehensively be explained by the theories of nonlinear dynamics, bifurcations and deterministic chaos. (Dr. M. Fette, System & Dynamics, Paderborn)

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Routes into Collapse

Through liberalization and deregulation of the power markets the complex load dynamics in electrical power systems are sustainably modified by an additional driving force. Consequently, the stability margins are thus more and more narrowed. If the power system gets into a highly stressed situation, the switching behaviour of the ULTCs of the transformers and the voltage regulators may aggravate the situation. Ultimately, they even contribute to the collapse of the whole power system.
Yet a long time before the collapse occurs, however, a so-called swing phase with special periodic and aperiodic superimposed oscillations can be detected (Fig. 1). It follows a drift phase with apparent silence, but of different time-scale for each collapse event. The duration length of this phase depends on the intensity of the preceding disturbance. In this phase the voltage, dependent on parameters, decreases and sometimes also increases. Shortly before the collapse event takes place the dynamics is abruptly changing again, resulting in the actual breakdown of the electrical power system (Fig. 2).

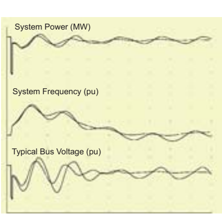


Fig. 1: Swing phase (IEEE)

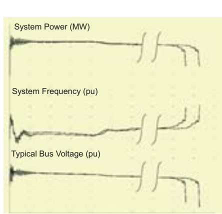


Fig. 2: Drift phase (IEEE)

The Diagnostic Lens

Reaching the critical Hopf-point which indicates the stability limit, causes the system to undergo a transition into an unstable periodic cycle. This transition is called Hopf-bifurcation. In this context, the location of the Hopf-point fully depends on the underlying load dynamics and thus may vary its position.

The subsequent approach to the Hopf-point can be diagnosed at an early stage by the detection of the emergence of superimposed oscillations at special frequencies (Fig. 3) and additionally by the evaluation of critical dynamics attached to these oscillations.

Conclusion: Collapses of electrical power systems can be predicted on time.

Blackouts can be avoided ...

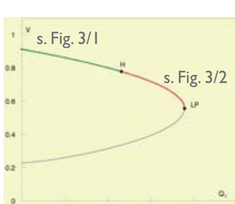
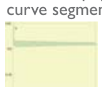


Fig. 3: Hopf point H and limit point LP

Fig. 3/1: Decreasing frequency before Hopf point H = green curve segment



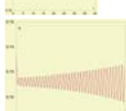
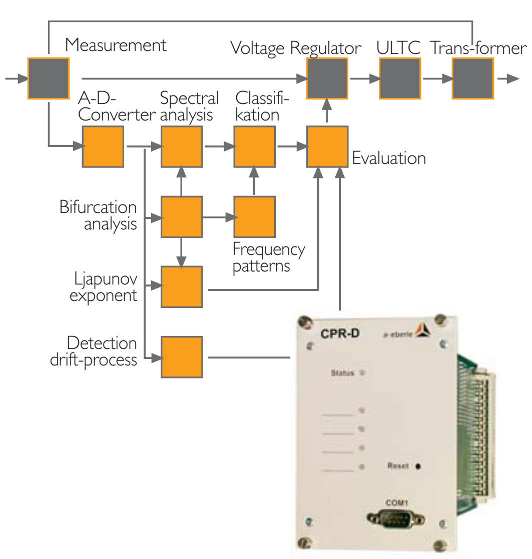


Fig 3/2: Increasing frequency after Hopf point H and before limit point LP = red curve segment

What to do

The CPR-D Collapse Prediction Relay is continually measuring the exact frequency lapse in the power net. The results of these measurements play the role of the sensory input for the permanent surveillance and assessment of the system dynamics.

If a dangerous situation is to be detected, the power system carrying company will immediately receive an alert message. This may initiate decisions of the operators to switch out the transformers by the regulating device to avoid further damage.



CPR-D Features

- Measurement of very low frequencies
- Evaluation of the characteristics of harmonics at the same time interval
- Intelligent adaptation of parameters for the measurement of frequencies
- Ascertainment of damping coefficients in the power net

CPR-D Functions

- Detection of critical collapse-specific frequencies patterns (fingerprints)
- Detection of creeping net breakdowns
- Frequency-Relay (load shedding)
- fault recorder
- Shutdown of transformer-ULTC after detection of criteria indicating a possible collapse

CPR-D Options

- Analysis and assessment of system dynamics
- Embedding in protection systems
- detailed alarm messaging