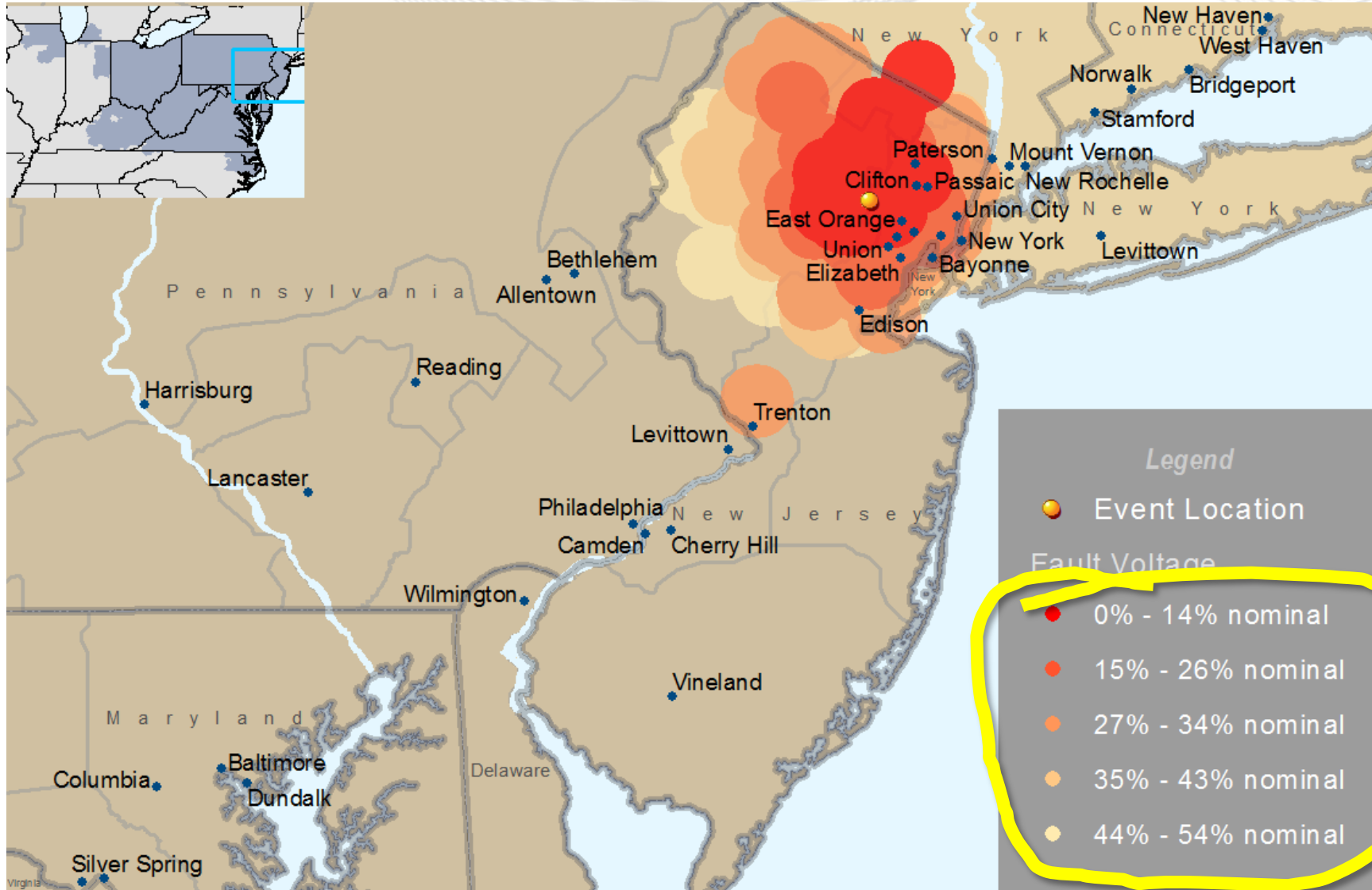


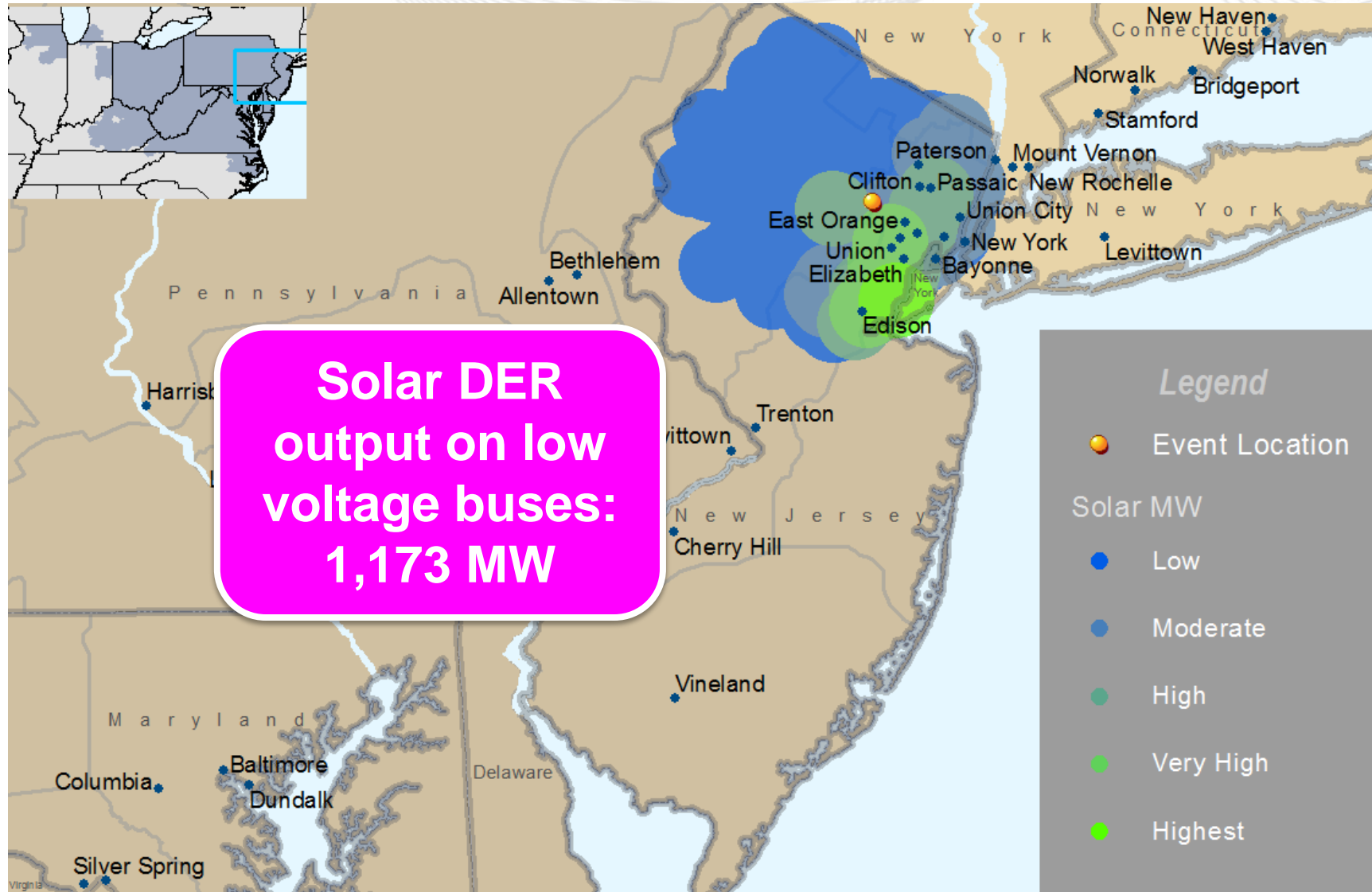
Aggregate impacts of DER on bulk system performance

Dr. Emanuel Bernabeu
Director, Applied Innovation and Analytics
Oct 1-2 PJM DER Ride Through Workshop

Transmission Voltage on 3-phase 230kV trip in summer 2021 at 2PM



Approx. solar output on low voltage buses in summer 2021 at 2PM

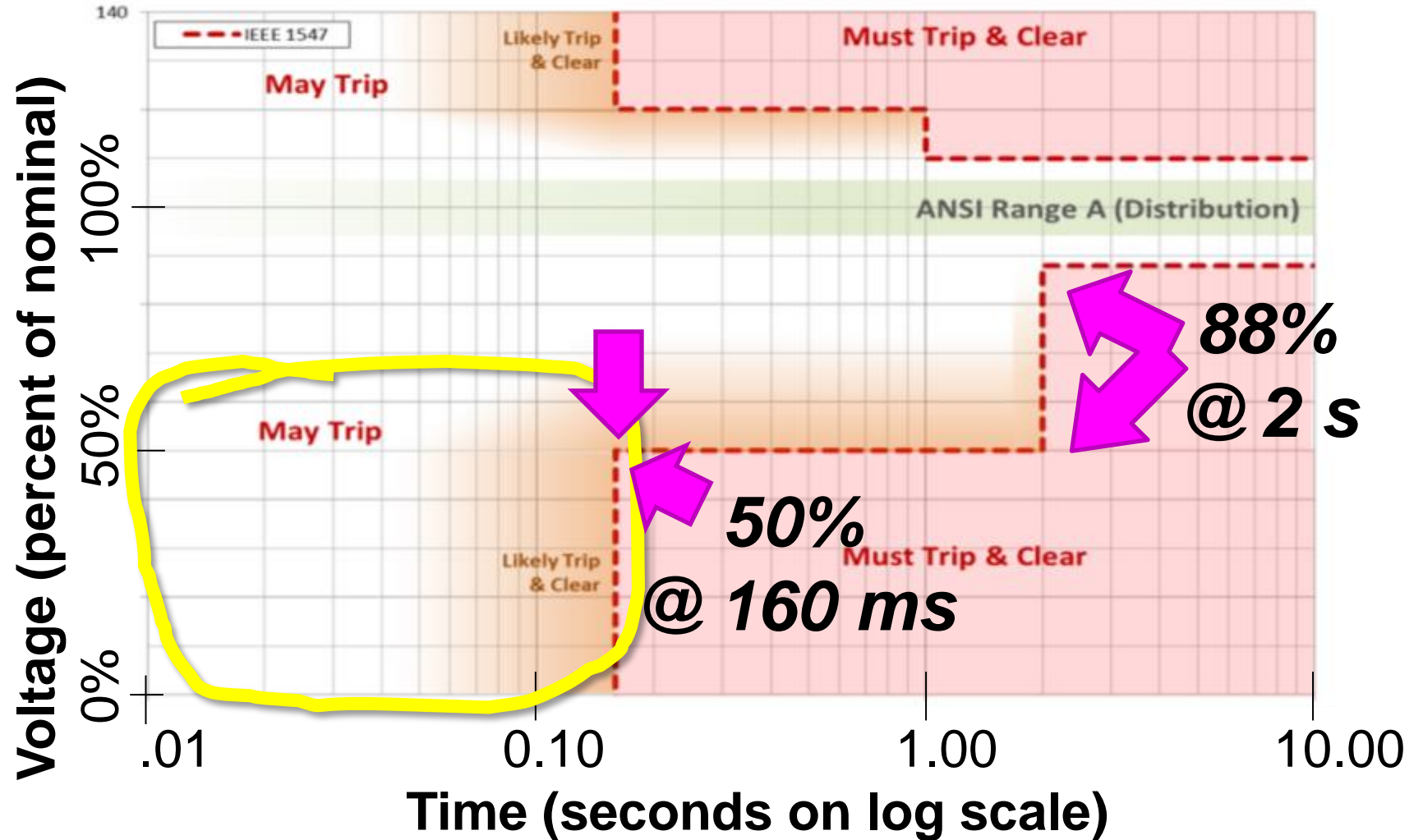


Status Quo—IEEE 1547-2003—DER and “Shall Trip”

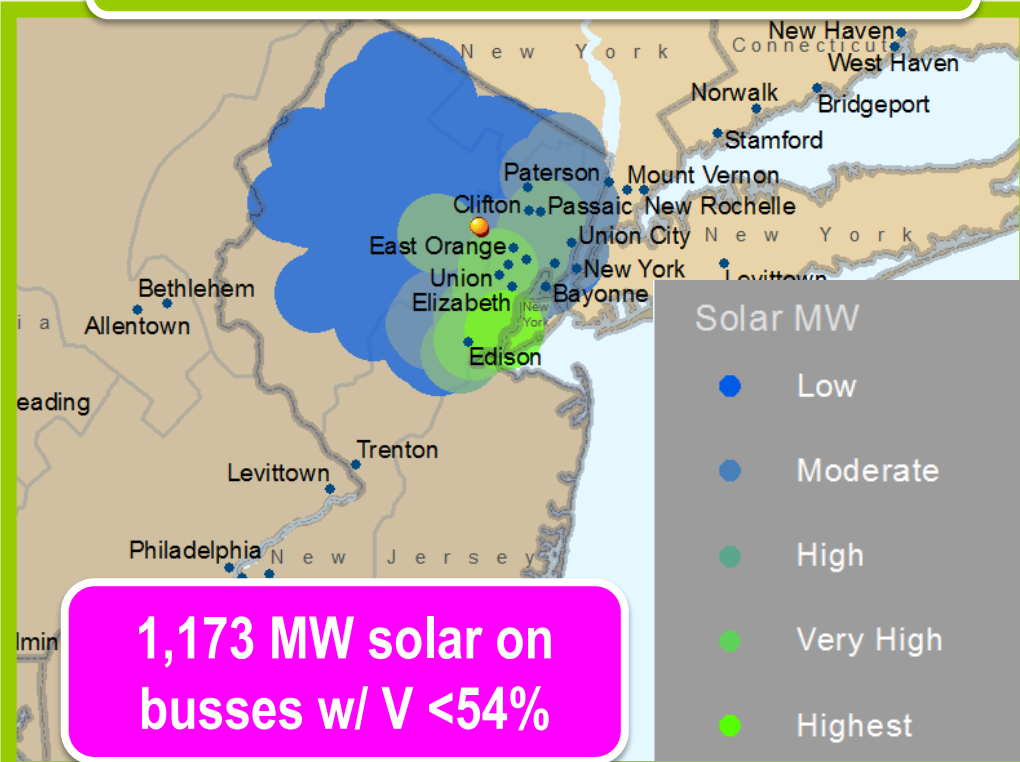
IEEE 1547 Standard Voltage Sensitivity

No ride through requirement

Shall trip in 160 ms $V < 50\%$



Multiphase transmission faults → wide area undervoltage



Fault-Induced Delayed Voltage Recovery > 2 s

Voltages on some transmission substation busses decayed to 50% or less of pre-fault conditions. Normal voltage restoration required an extended period of time, estimated to be between 5 and 15 seconds.

15s FIDVR 1992 PECO line-line-ground fault*

Delayed transmission fault clearing

Reclosing and trip timing accumulation

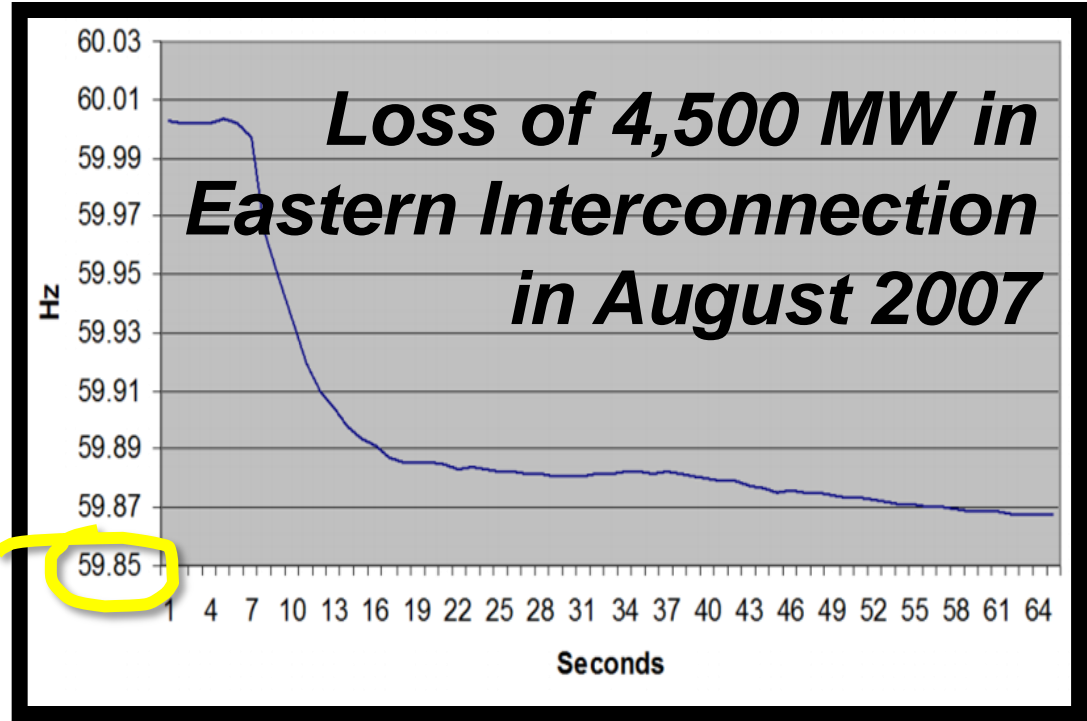
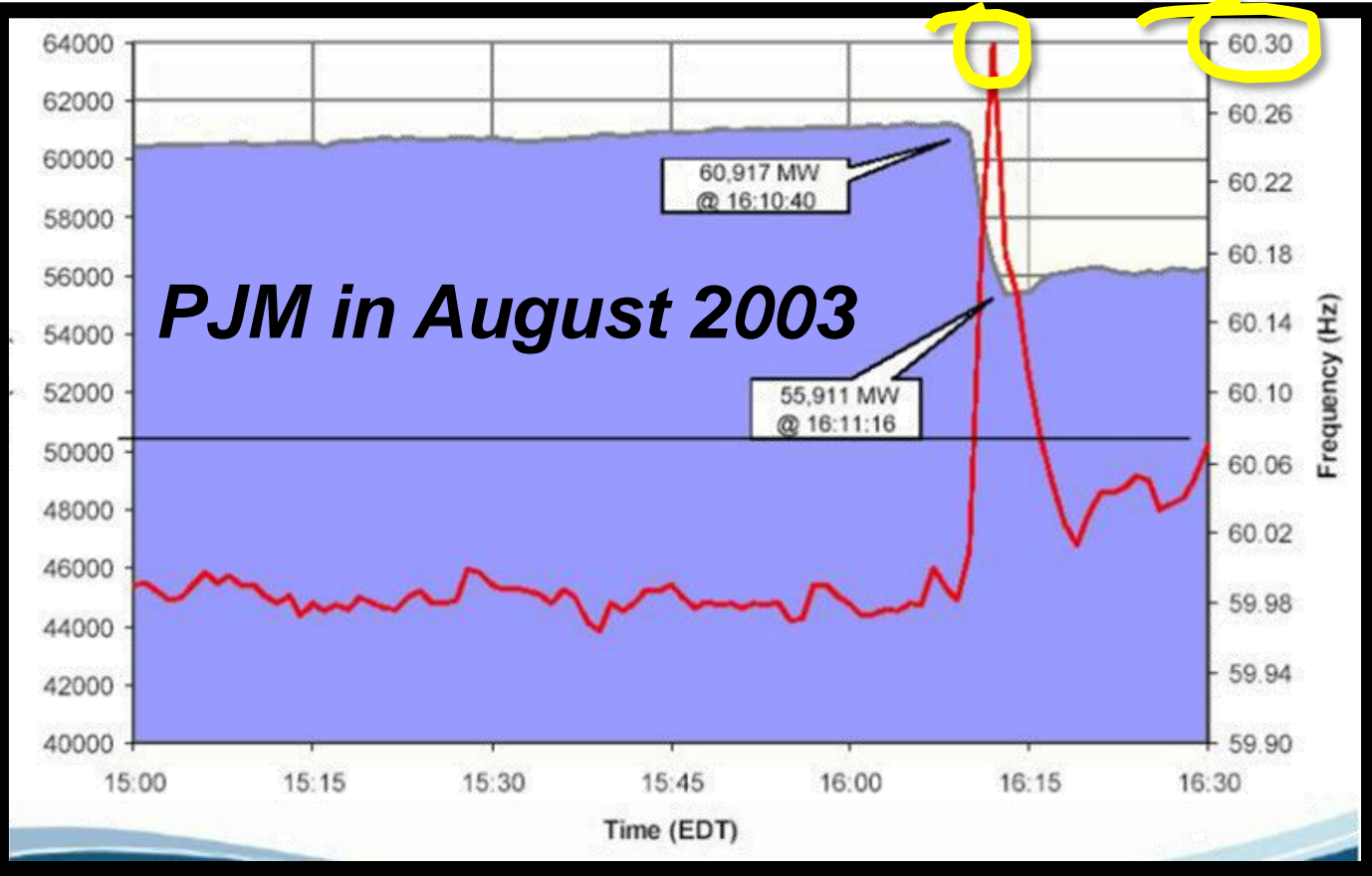
* EPRI/NERC FORUM ON VOLTAGE STABILITY at 2/15-24 (Breckenridge, Colo., Sept. 1992) (EPRI TR-102222).

Could 60.5 or 59.8 Hz frequency trip of DER impact PJM?

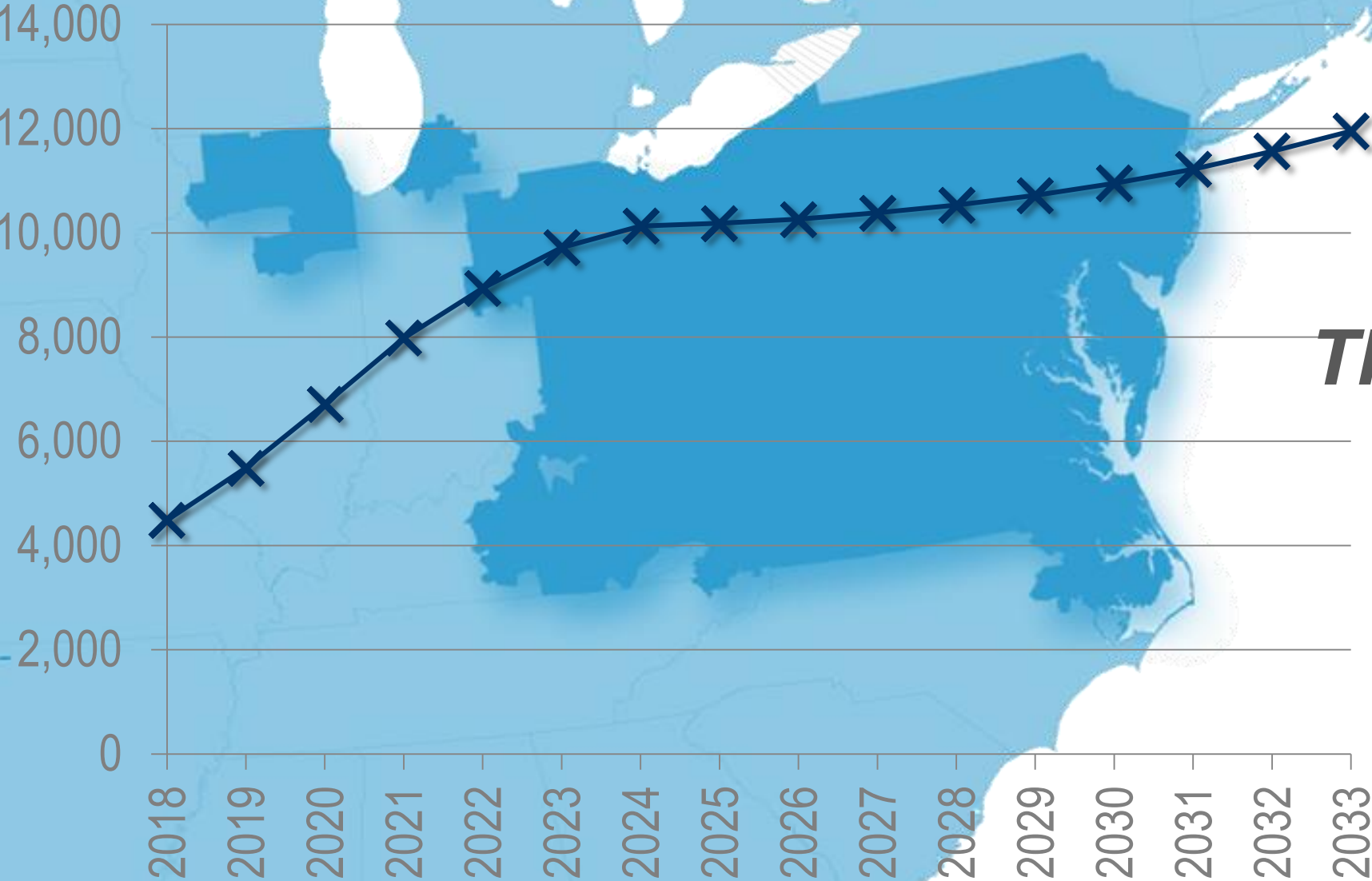
Catastrophic islanding of interconnection

Black start

Unusually Big Gen Loss



PJM SOLAR DEPLOYMENT FORECAST



DER RIDE THROUGH (AND LONGER TRIP TIMING) IS NOW A PRIORITY