ARIZONA STATE UNIVERSITY · EEE 489 SENIOR CAPSTONE · SPRING 2026

Wind Turbine Grid Impact Study

Transient Stability Analysis of a Type III DFIG Integrated into the IEEE 39-Bus System

Cameron Woods ◆ Naeim Naeimi ◆ Sari Alhujuri ◆ Ibrahim Alanazi ◆ Caden Holliday

Mentor: **Dr. Vijay Vittal** | Area 51 | Ira A. Fulton Schools of Engineering

39
BUS SYSTEM

30+
FAULT CASES

DFIG
TYPE III TURBINE

01 · BACKGROUND

Motivation

Wind penetration in modern grids is accelerating rapidly. Unlike synchronous generators, Type III doubly-fed induction generators (DFIGs) interact with the grid through partial-scale power-electronic converters, introducing new transient stability challenges including voltage flicker, harmonic distortion, and rotor angle instability during fault events.

This project integrates a DFIG into the IEEE 39-bus New England benchmark network — 10 generators, 46 transmission lines — to evaluate grid stability under a comprehensive set of three-phase fault scenarios.

02 · METHODOLOGY

Simulation Workflow

PSAT — Steady-State Verification
Power flow confirms bus voltages, generator dispatch, and network balance with DFIG integrated. Establishes a physically consistent base case required for valid dynamic simulation.

TSAT — Transient Fault Simulation
Three-phase faults applied at every bus; generator rotor angle trajectories tracked over 10 seconds. Stable if all angles remain bounded and converge post-fault.

Type III DFIG Model
DFIG with partial-scale converter, PLL synchronization, and reactive power control. Parameterized from literature to reflect GE 2.5-MW class turbine behavior.

03 · SYSTEM SPECIFICATIONS

Turbine type	Type III (DFIG)
Grid interface	Partial-scale converter
Synchronization	Phase-Locked Loop (PLL)
Grid model	IEEE 39-bus NE system
Simulation tools	PSAT + TSAT (Apporto)
Wind connection	Bus 31 (DFIG replaces Gen)
Observation window	10 seconds post-fault
Budget	$200 (simulation-only)

04 · NETWORK MODEL

IEEE 39-Bus System

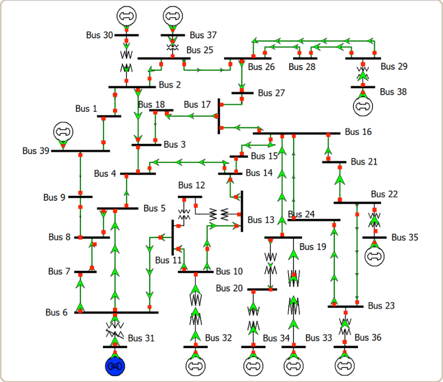
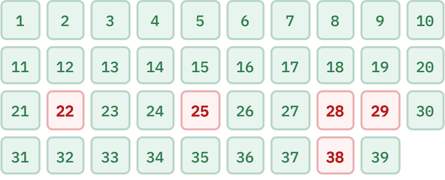


Fig. 1 — IEEE 39-bus New England test system. DFIG connected at Bus 31 (blue). Generators shown as circles; red squares are measurement/fault points.

05 · FAULT STABILITY MAP

All 39 Buses Tested

● Stable ● Unstable / FAIL



🟩 1	🟩 2	🟩 3	🟩 4	🟩 5	🟩 6	🟩 7	🟩 8	🟩 9	🟩 10
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🟩 21	🟥 22	🟩 23	🟩 24	🟥 25	🟩 26	🟩 27	🟥 28	🟥 29	🟩 30
🟩 31	🟩 32	🟩 33	🟩 34	🟩 35	🟩 36	🟩 37	🟥 38	🟩 39	

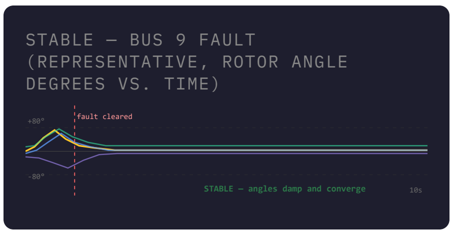
* Buses 25, 28, 29 stable under single-line fault; fail under N-1-1 line contingency

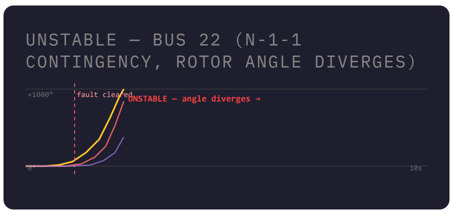
KEY FINDING

35 of 39 buses remain transiently stable. Critical instability concentrated in the northeastern tie-line corridor (buses 22, 25–29), where N-1-1 contingencies sever inter-area power transfer paths and cause rotor angle divergence.

06 · ROTOR ANGLE RESPONSE

Stable vs. Unstable Faults


STABLE — BUS 9 FAULT (REPRESENTATIVE, ROTOR ANGLE DEGREES VS. TIME)


UNSTABLE — BUS 22 (N-1-1 CONTINGENCY, ROTOR ANGLE DIVERGES)

07 · RESULTS SUMMARY

✓ **35 / 39 buses stable** — rotor angles bounded and converging within 10s. DFIG reactive power support improved post-fault voltage recovery at neighboring buses.

✕ **Buses 22, 25–29 vulnerable** — northeastern corridor collapses under N-1-1 contingency. Loss of tie lines 25–26 or 28–29 isolates subnetwork causing rotor divergence.

! **Buses 19 & 38 show residual instability** under current model parameters — converter and control tuning in progress.

To address the identified instability and power quality issues, the system will be refined through targeted adjustments to both network configuration and control dynamics. This includes tuning the DFIG converter and phase-locked loop (PLL) parameters to improve synchronization and damping of rotor angle oscillations, as well as modifying power flow distribution to reduce stress on weak buses. Additional reactive power support will be implemented to stabilize voltage during fault conditions, and contingency scenarios will be rebalanced to prevent isolation of critical tie-line corridors. Together, these adjustments will improve transient stability, ensure bounded rotor angle response, and enable the system to maintain reliable operation under both faulted and variable wind conditions.

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