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ADVANCING THE OPERATIONAL FLEXIBILITY OF D-336 GAS TURBINE UNITS FOR ANCILLARY SERVICES THROUGH ADAPTIVE AIR BLEED CONTROL SYSTEMS

Abstract. The D-336 gas turbine engine, a cornerstone of the 6.3–8 MW power generation segment, traditionally operates in a rigid isochronous mode to maintain a constant 50 Hz grid frequency [1]. However, its potential for participating in the Ancillary Services Market (ASM) – specifically in Frequency Restoration Reserves (FRR) – is limited by its transient stability during abrupt load changes. A critical challenge is the 100% full load rejection, where a severe pneumatic-to-thermal imbalance leads to combustion flameout due to an excessive air-fuel ratio (AFR) [2].

The Problem of Transient Stability. Conventional non-controlled pneumatic air bleed valves (ABVs) exhibit a latency of 100–200 ms, failing to intercept the flameout development window of 80–150 ms. This technical bottleneck results in a 60–70% failure rate during full load rejection, leading to immediate unit trips and significant grid instability.

Proposed High-Speed Adaptive Control. This study proposes a high-speed modernization of the air bleed system, transforming existing ABVs into **Controlled Air Bleed Units**. The system integrates ultra-fast solenoid pilot valves (5–10 ms) and a predictive microprocessor-based control logic [3]. The core innovation lies in the **Pre-emptive Bleed Activation** – a proactive opening of the ABVs initiated 30 ms prior to the actual generator circuit breaker trip. This allows for controlled depressurization of the compressor discharge before the fuel control valve reaches its minimum stop.

Results and Performance Metrics. The implemented algorithm optimizes the entire operating envelope of the D-336 engine. Key performance indicators include:

– **response Time:** Valve actuation is achieved within ≈50 ms (2–4 times faster than the OEM system).

– **flameout Mitigation:** Probability of combustion extinction is reduced to < 5%.

– **operational Range:** The unit gains the ability to execute seamless transitions across the full load spectrum, from 0% to 100%, without risking a total shutdown.

Strategic Impact on the Energy Market. By ensuring guaranteed 100% load rejection and rapid re-loading capabilities, the D-336 GTE can fully leverage its potential in the ancillary services market. This modernization facilitates:

– **grid Stability:** Enhanced contribution to primary and secondary frequency control.

– **economic Efficiency:** Reduced generation losses of 12–21 MWh/year and high ROI with a 2 – 6 years payback period.

– **asset Resilience:** Minimized thermal stress and mechanical fatigue during emergency trips.

Conclusion. The transition to solenoid-actuated, predictive air bleed control is a critical technological upgrade for the D-336 fleet. It transforms a standard power unit into a highly flexible grid asset. This modernization is not only economically viable but essential for the integration of gas turbine power plants into the modern, volatile energy landscape of Ukraine, ensuring both energy security and market competitiveness.

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