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Technical Disclosure[1]

1. Title

Method for Failed or Missing Control Card Detection in a Wind Turbine Power Converter System

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4. Publication type

Technical Disclosure

5. Abstract

This disclosure relates to diagnostics and startup-state management for a wind turbine power converter system in which peripheral control cards, printed circuit board assemblies (PCBAs), insulated-gate bipolar transistor (IGBT)-related modules, and associated converter components may be failed, damaged, disconnected, or missing. The disclosed approach leverages existing electronic and electrical signals, including communication over a high-speed serial link (HSSL), to determine the identity of specific peripheral components present in the converter cabinet and to detect a fault condition associated with a specific failed or absent component. Rather than allowing a single component fault to trigger a cascade of misleading diagnostic messages and a full converter freeze, the system identifies the failed component deterministically, suppresses secondary or cascading diagnostic errors, and transitions the converter into a partial operational state. In that state, at least selected secondary subsystems, such as heater, fan, cooling, or other environmental control functions, remain operational based on data from healthy remaining components, while the hardware device report clearly indicates which boards are present and which are missing. This reduces troubleshooting time, avoids unnecessary replacement of healthy parts, and improves field serviceability of wind turbine converter systems.

6. Technical field

The disclosure is in the field of wind turbine electrical power conversion and converter diagnostics, and more specifically relates to fault detection, component identification, startup control, partial-operation management, and service diagnostics for peripheral cards and related hardware within a wind turbine power converter cabinet.

7. Background

Wind turbine converter subsystems include multiple peripheral cards and converter electronics whose failure can significantly affect turbine availability. According to the disclosure, PCBA cards and IGBTs are among the highest drivers of unplanned service visits in the converter subsystem. Existing systems do not provide clear diagnostics when such components fail, are damaged, or

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become disconnected. Instead, the diagnostic system may generate numerous confusing messages that obscure the root cause.

When a phase module fails, it may damage associated gate driver interface cards, and the converter diagnostics may then present a large number of confusing messages, with a visible trip message that is not necessarily the first or true fault. As a result, technicians may replace easily accessible components, even when those parts are not the actual cause of failure. This trial-and-error troubleshooting approach requires multiple up tower climbs, increases time to resolve field cases, and can lead to replacement of healthy components.

The disclosure also notes that legacy behavior may cause thermal control of heaters and fans to freeze when faults occur, even though maintaining such environmental control may be desirable to protect remaining healthy equipment.

8. Summary of the disclosure

This disclosure introduces a method for startup and diagnosis of a wind turbine power converter system in which the converter monitors the presence of a plurality of peripheral components within a converter cabinet via HSSL to obtain specific component IDs, detects a fault condition associated with one or more specific peripheral components, and enters a partial operational state when such a fault is detected.

In the partial operational state, the system:

- identifies the specific failed peripheral component,

- suppresses cascading or misleading diagnostic errors related to the failure, and

- maintains operation of at least one secondary subsystem, such as thermal management or environmental control, using information from remaining healthy peripheral components.

The disclosure emphasizes two central concepts:

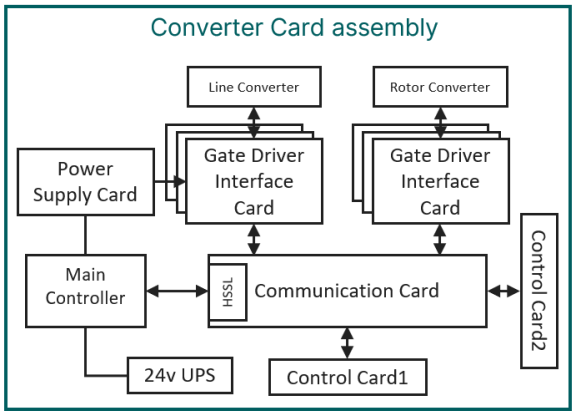
1. Replacement of guesswork with deterministic identification of the failed hardware component using existing sensor and communication channels; and

2. Replacement of total freeze with partial operation, enabling stable non-generating or non-converter-running behavior while preserving useful support functions and providing a clear hardware inventory/report of present and missing boards.

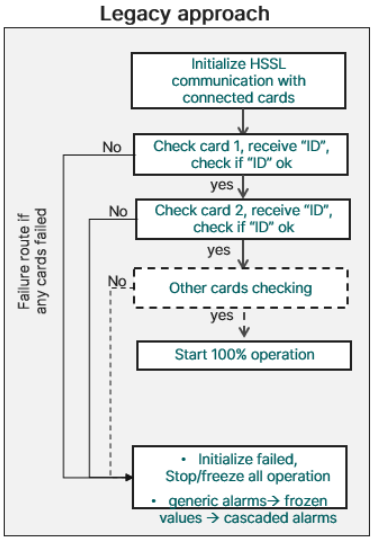
9. Brief description of drawings

By way of example, the drawings and diagrams relating to:

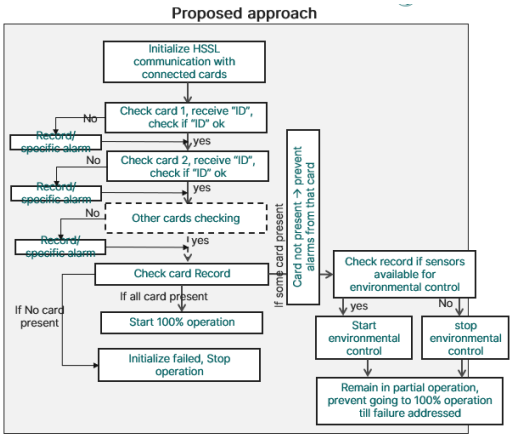
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- a converter card assembly architecture including main controller, associated peripheral cards such as communication cards, control cards, gate driver interface cards of phase modules, power supply card, line converter, rotor converter, HSSL, and 24V UPS;



- background fault-propagation behavior showing confusing diagnostics resulting from card disconnection or damage;



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- a proposed approach as suggested by this disclosure;

10. Detail description

A wind turbine power converter system typically includes multiple peripheral cards, control cards, phase-module-associated interfaces, environmental control interfaces, and power electronics arranged in a converter cabinet.

In one implementation, during startup or initialization of the converter system, the controller monitors the presence and identity of peripheral components connected within the cabinet. This monitoring may be performed via high-speed serial link (HSSL) communication, through which the system can obtain a specific component ID or otherwise determine whether a given card or module is valid, present, responsive, or missing.

The controller evaluates the obtained information to detect whether at least one peripheral component is failed, damaged, disconnected, invalid, or absent. Rather than permitting the initialization routine to proceed in a manner that causes a broad failure cascade, the controller uses the component-identification information to associate the abnormal condition with a specific peripheral component. In this way, the system can generate a focused diagnostic message identifying the actual hardware item requiring inspection or replacement.

The proposed method uses existing sensor and data communication channels to determine which devices have failed. This means that the system need not rely on a wholly separate diagnostic network but can instead leverage signals already available in the converter architecture to determine board presence and fault status.

The method describes a partial running case or partial stable/complete state. In legacy operation, if any relevant card was not valid, the initialization process could end in a failure case after passing through multiple cases, with the converter effectively freezing and generating multiple unrelated or derivative fault messages. In the improved design, if some cards are missing, the state machine can remain in or transition to a partial stable state in which some functions are still controlled, including heater and fan control.

This partial operational state may have several characteristics:

- HSSL remains active as long as certain key components, such as critical communication cards and HSLA target, are present;

- the hardware device report is populated with the boards that are present;

- the hardware device report clearly indicates which boards are missing;

- the converter is prevented from entering a normal run state if necessary; and

- secondary subsystems, particularly thermal control, remain functional when sufficient supporting control cards, are available.

The disclosure expressly notes that in the partial stable/complete state, if all control cards related to environmental control are present, control of heaters and fans must be functional regardless of which other boards are missing or damaged, including phase module and its associated peripheral

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cards. Control cards related to environmental control may include relay outputs, PWM fan outputs from communication cards, and environmental control signals over IONet to turbine control.

An important aspect of the disclosure is suppression or masking of irrelevant cascading diagnostic errors. A missing or damaged circuit card should result in a single diagnostic that clearly identifies which part should be examined, while masking or disabling unrelated diagnostics such as downstream messages relevant to the missing card. This sharply reduces diagnostic clutter.

The disclosure therefore converts a service process previously dominated by subjective interpretation and trial replacement into an objective and deterministic process. A technician receiving the diagnostic output can identify the failed board directly, reducing unnecessary replacement of healthy cards and reducing repeated turbine climbs.

11. Advantages

The disclosed approach provides several advantages:

- Clear fault isolation: identifies the specific failed peripheral component rather than presenting ambiguous or cascading errors.

- Reduced troubleshooting time: technicians no longer need to rely on repeated uptower trial-and-error component replacement.

- Reduced replacement of healthy components: the deterministic diagnostic reduces misdiagnosis of accessible but healthy cards.

- Suppression of cascading diagnostic messages: legacy noise or secondary fault messages can be masked so that root-cause diagnosis is clearer.

- Partial operation instead of total freeze: the converter can remain in a controlled, stable, non-run partial state rather than collapsing into full shutdown logic.

- Continuation of environmental control functions: heaters, fans, and related thermal management functions can remain operational when supported by healthy remaining components.

- Improved serviceability and maintainability for wind turbine converter cabinets in the field.

12. Example Embodiments

Embodiment 1: HSSL-based startup detection of missing peripheral cards

A converter controller performs startup initialization and queries multiple peripheral boards over HSSL. The controller receives component IDs or validity responses from the connected cards. If one board does not respond or reports invalid status, the controller logs that board as failed or missing and enters a partial stable state instead of allowing a full cascading failure response.

Embodiment 2: Single diagnostic output for damaged phase-module-related cards

A phase module failure causes secondary damage to its associated peripheral cards. Rather than reporting numerous unrelated converter diagnostic messages, the controller suppresses secondary fault messages and outputs a single diagnostic indicating the most likely failed component or set of failed cards to be examined.

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Embodiment 3: Partial stable state with maintained heater and fan control

Upon detection of missing nonessential boards, the converter enters a partial stable/complete state in which HSSL remains active and the hardware device report displays present and missing boards. If environmental control related cards remain healthy, heater and fan control continues to operate, thereby preserving environmental control in the cabinet while the converter is prevented from normal power-conversion running.

Embodiment 4: Improved device reporting during optical cable disconnection

As an example, if communication/power connection of a gate driver interface card is disconnected. The system detects the resulting device absence or communication/power supply fault, updates the device report accordingly, and avoids generation of unrelated legacy diagnostics that might otherwise obscure the root issue.

Embodiment 5: Inventory reporting for disconnected control cards

Where control cards disconnected, the system updates inventory or hardware device reporting to indicate the specific missing cards and uses that result to support service action and preserve appropriate partial-operation behavior.

13. Industrial Applicability

The disclosure is applicable to utility-scale wind turbines, especially turbines using converter cabinets with multiple peripheral control cards and high-speed internal communication links. It is particularly useful for fleets where converter-card failures and associated diagnostics contribute materially to unplanned maintenance events.

The method is applicable in manufacturing, commissioning, field operation, maintenance diagnostics, retrofit programs, reliability improvement initiatives, and service workflows intended to reduce turbine downtime and maintenance cost.

14. Variations and Alternatives

Many implementations are possible within the scope of the disclosure. For example:

- The communication path used to detect component identity need not be limited to HSSL, although HSSL is specifically disclosed.

- The peripheral components monitored may include different card families, phase-module interfaces, sensor boards, power-electronics interface boards, environmental control boards, or other converter subassemblies.

- The partial operational state may be configured differently depending on product architecture, such as allowing selected subsystems to remain active while explicitly preventing torque production. for example.

- The hardware report may identify present and missing devices through text, codes, graphical service interfaces, logs, or remote monitoring outputs.

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- Diagnostic suppression logic may be implemented as masking, prioritization, root-cause filtering, correlation, or state-dependent alarm inhibition.

- The same diagnostic concept may be extended to older or newer DFIG platforms or to full-converter wind turbine architectures if comparable card-detection channels and startup logic are available.

15. Conclusion

This disclosure provides a practical and technically grounded method for identifying failed or missing peripheral control hardware in a wind turbine power converter system. By using existing sensor and communication channels, including HSSL-based detection of component identity and presence, the system can determine the specific failed component, suppress misleading cascading diagnostic messages, and transition into a partial operational state that preserves useful secondary functions such as environmental control. The result is a more serviceable converter platform with clearer diagnostics, reduced technician guesswork, fewer unnecessary part replacements, and improved field-maintenance efficiency.

Abbreviations:

PCBA	Printed circuit board assembly
IGBT	Insulated-gate bipolar transistor
HSSL	High-speed serial link
ID	Identifier
UPS	Uninterruptable power supply
HSLA	High-speed link adapter
PWM	Pulse width modulation
IONet	Input/output network
DFIG	Doubly fed induction generator

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