Technical Disclosure[1]

1. Title

Through-Door Modular Converter Installation System and Method for Wind Turbine Repower Applications

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Technical Disclosure

5. Abstract

A system and method are disclosed for installing modular power-converter cabinets into a wind turbine tower through a tower door during repower, retrofit or repair operations. The disclosed approach enables multiple converter-related cabinets and associated components to be introduced through a constrained tower-door opening using coordinated external and internal lifting equipment, a telescopic sliding structure or "sleigh," support and reinforcement tooling, temporary floor panels, and optional pulling hardware. The method includes preparing the turbine and tower platform, verifying door compatibility, reinforcing the working surface, positioning a sleigh aligned with the tower doorway, transferring cabinets from external handling equipment to the sleigh and internal lifting arrangements, and moving the cabinets into final positions inside the tower. The approach supports installation of cabinets such as a converter filter cabinet, power distribution cabinet, converter bridge cabinet, and master control cabinet, and may further include use of a converter lift beam and restoration steps following installation. The disclosed techniques improve serviceability, reduce dependence on major disassembly pathways, support repower execution in constrained access conditions, and provide a controlled process for moving large electrical cabinets into a turbine tower.

6. Technical field

The present disclosure relates generally to wind turbine repower and retrofit operations. More particularly, the disclosure relates to systems, tooling arrangements, and installation methods for transporting and installing modular converter and related electrical cabinets through a wind turbine tower door and into an internal tower platform space.

7. Background

Wind turbine repower projects often require replacement or upgrade of converter and electrical control equipment located within the tower. Such equipment may include high-mass or bulky cabinets with dimensions that create access challenges during removal and reinstallation. In many field conditions, the tower door provides a limited opening, and the internal platform area may

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contain holes, edge gaps, structural limitations, and obstructions that complicate movement of heavy cabinets.

Traditional replacement methods may rely on extensive disassembly, larger external lifting campaigns, or removal paths that are difficult to execute consistently across turbine variants and site conditions. In addition, heavy cabinet movement through a tower doorway presents risks associated with suspended loads, cabinet stability, platform loading, pinch points, and emergency egress obstruction. Wind conditions, internal space constraints, and alignment tolerances can further complicate the installation process.

Accordingly, there is a need for a controlled and repeatable system for introducing modular converter cabinets through a turbine tower door using coordinated lifting, sliding, and rendering operations while preserving safety, minimizing structural interference, and supporting efficient repower execution.

8. Summary of the disclosure

The disclosure describes a modular installation architecture and associated work method for through-door installation of converter-related cabinets in a wind turbine tower.

In one aspect, the disclosure provides a tooling arrangement including one or more of:

- a telescopic slide structure or sleigh positioned at the tower doorway;
- a crane mat or support base for the sleigh;
- platform reinforcement members such as tripod jack stands or equivalent supports;
- temporary floor-hole and edge-gap panels;
- a portable hoist or internal hoist arrangement;
- external lifting equipment such as a telehandler, jib, boom, or rigged lift interface;
- a lift beam for controlled cabinet handling;
- rigging hardware including slings, shackles, hooks, lifting eyes, and a load cell; and
- an optional pulling system mounted away from the door to assist final cabinet movement where the tower lacks suitable pulling bosses.

In another aspect, the disclosure provides a method including preparation of the turbine, verification of tower door dimensions and compatibility, installation of support tooling, placement and alignment of the sleigh at the doorway, loading and securing cabinets for transfer, coordinated pulling and lifting of cabinets into the tower, and placement of the cabinets in installed positions.

In a further aspect, the disclosure supports installation of multiple cabinet types, including a converter filter cabinet (CFC), power distribution cabinet (PDC), converter bridge cabinet (CBC), and master control cabinet (MCC), and may include associated heat exchanger or fan-related equipment. Different cabinet types may use different rigging points, lifting-eye sizes, slide-extension limits, and final positioning sequences.

The disclosed approach enables large electrical cabinets to pass through a tower door opening in a controlled sequence using a combination of external rendering forces and internal hoisting support, thereby facilitating repower operations without requiring less practical access routes or excessive structural disassembly.

9. Brief description of drawings

Figure 1 may illustrate an example rigging arrangement for lifting converter cabinets, including lifting eyes, slings, shackles, hooks, master links, and winches.

Figure 2 may illustrate reinforcement of the internal platform by placement of support jacks beneath the platform.

Figure 3 may illustrate an optional pulling system mounted relative to foundation studs opposite the tower door.

Figure 4 may illustrate a crane mat or base support positioned outside the tower door.

Figure 5 may illustrate a sleigh or telescopic slide structure for cabinet transfer through the doorway.

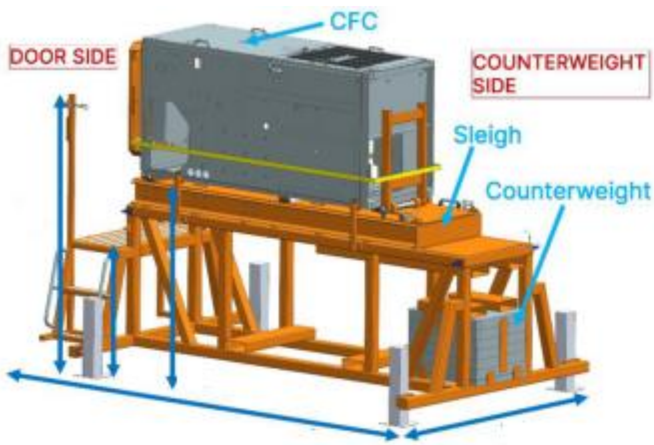


Figure 6 may illustrate external lifting or telehandler interaction with the cabinet during loading.

Figure 7 may illustrate cabinet securement on the sleigh.

Figure 8 may illustrate cabinet movement from the sleigh into the tower.

Figure 9 may illustrate a converter lift beam assembly.

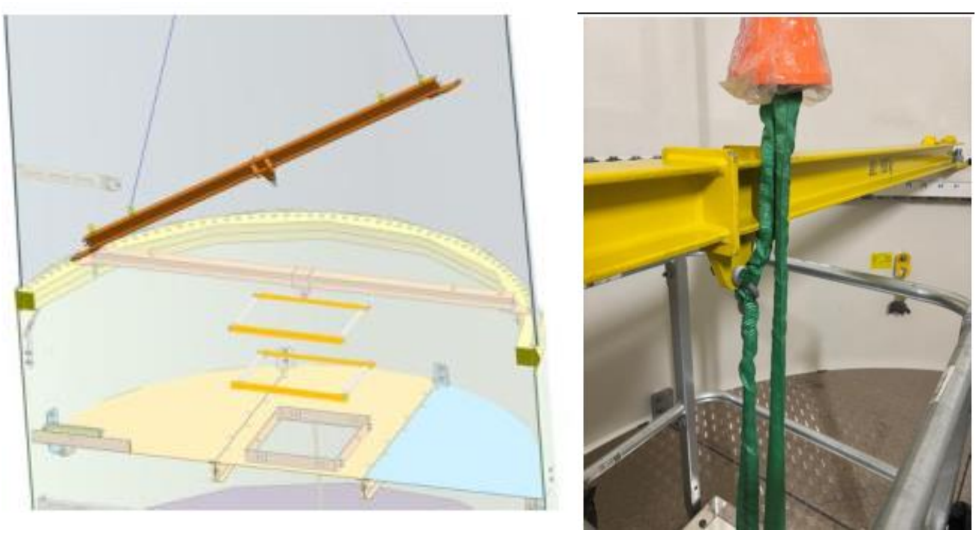
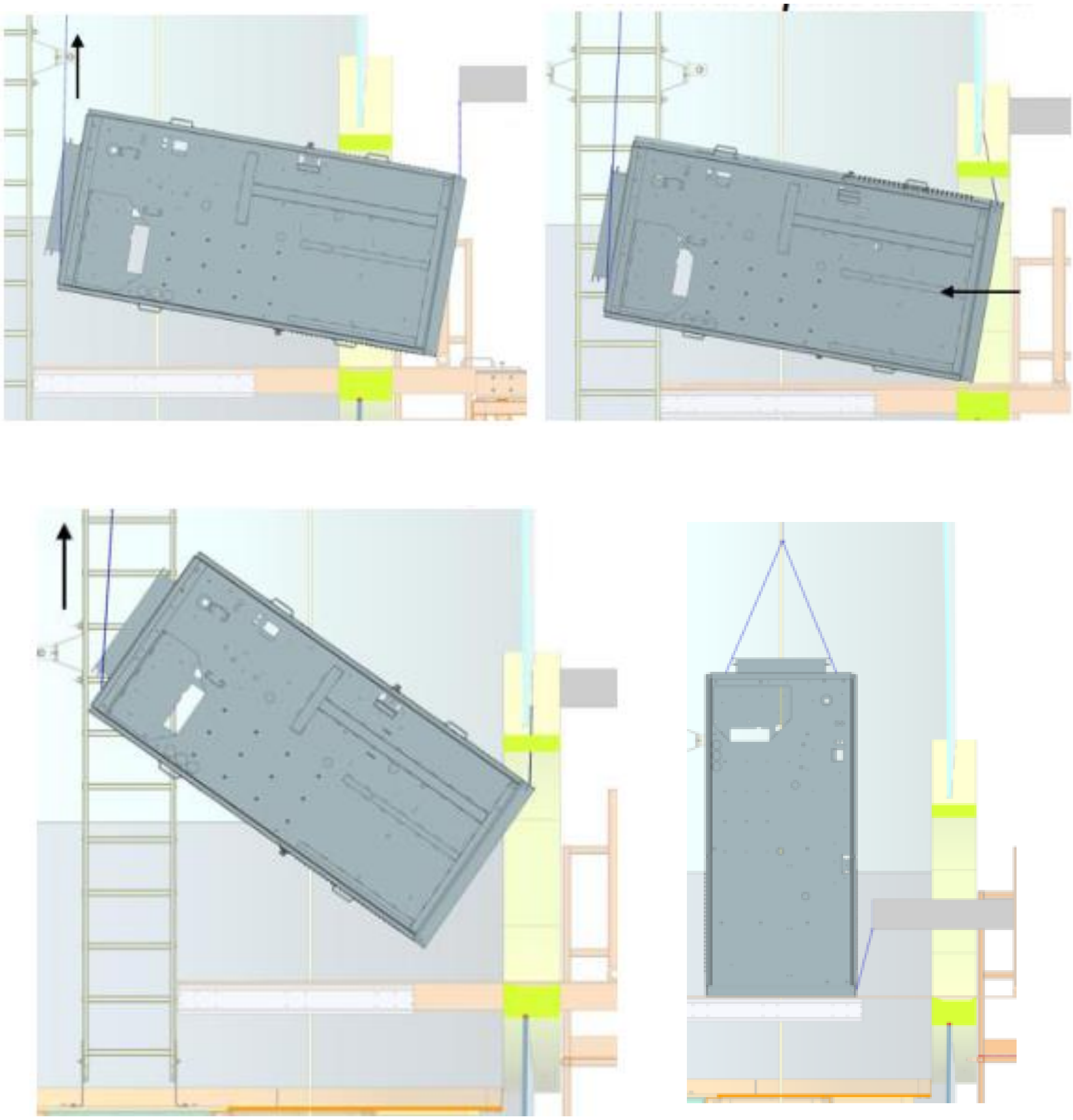


Figure 10 may illustrate final installation sequences



10. Detail description

The disclosure is directed to a through-door installation system and method for modular converter cabinets used in wind turbine repower applications. The system is particularly useful where cabinet replacement or upgrade must be performed through an existing tower door opening and where the internal tower platform requires temporary structural preparation to support cabinet handling.

10.1 System context

A wind turbine tower may contain converter and control equipment arranged as multiple cabinet modules. In representative implementations, these may include:

- a liquid-air heat exchanger (LAHE), where applicable;

- an air-air heat exchanger (AAHE), where applicable;
- a master control cabinet (MCC);
- a converter bridge cabinet (CBC);
- a converter filter cabinet (CFC); and
- a power distribution cabinet (PDC).

The disclosed method is especially suited for repower tasks involving installation of the CFC, PDC, CBC, and MCC through the tower door after preparatory work and, where needed, prior disassembly or reassembly operations handled by associated procedures.

10.2 Pre-installation preparation

Before cabinet movement begins, the turbine and worksite are evaluated for suitability. Preparation may include confirmation that task-specific job planning, hazard review, and work authorization documents are complete. The condition of the turbine, adjacent work, weather, and any alternate or induced electrical energy sources are reviewed. Wind-speed limitations applicable to the turbine and to the specific tools or operations are also verified.

The tower door is measured or otherwise checked to ensure compatibility with the intended through-door installation tooling and cabinet path. In some implementations, a tower-door retrofit or modified door condition may be required to achieve adequate clearance.

The work area is then prepared for cabinet movement. Because the internal platform near the door may not be suitable for direct cabinet loading without reinforcement, the platform is reinforced using jacks, such as tripod jack stands, placed beneath or near the work zone. Protective slide or wear plates may be placed on the platform surface to prevent damage during cabinet movement.

Where the tower floor contains openings or edge gaps, temporary panels are installed to cover the holes and create a more continuous movement path. Additional panels may be bolted or clamped in position to bridge edge regions or intermediate gaps.

10.3 Tooling and lifting arrangement

The disclosed system may employ both general and special tools. Representative equipment includes rigging hardware, calibrated torque tools, radios, digital levels, tie-down straps for securement, cribbing, fire extinguisher support, load cells, hooks, shackles, carabiners, synthetic slings, lifting eyes, chain hoists, electric winches, and a portable electric hoist.

Special tools may include:

- a telehandler with extendable boom;
- a telehandler jib attachment;
- a lift beam for first-deck or initial installation operations;
- a telescopic slide tool or sleigh with counterweight;
- a generator for powering a tower hoist;

- a crane mat for positioning the sleigh;
- hardwood cribbing blocks;
- an optional pulling system; and
- custom cribbing or protection elements for selected cabinets such as the CFC.

A rigging configuration may be selected according to cabinet type. For example, different cabinets may use different lifting-eye sizes, such as M10, M12, or M16 lifting eyes. In representative lifting practice, two slings may be tensioned while two others remain comparatively slack, depending on cabinet geometry and desired orientation. A load cell may be used to monitor lifting loads during transfer.

10.4 Installation of support tooling

Once the platform is reinforced and protected, a pulling system may optionally be installed if the tower lacks usable structural bosses for drawing a cabinet into final position. In one implementation, the pulling system is mounted to foundation studs approximately opposite the tower door and adjusted to a level or door-away orientation using adjustable feet. This pulling system may assist with final CFC positioning or related cabinet movement.

Temporary panels remain in place to cover floor openings and to reduce the risk associated with cabinet wheels, bases, or slide structures encountering discontinuities in the platform surface.

10.5 Positioning of the sleigh

A main structural transfer device, referred to herein as a sleigh, is positioned in front of the tower door. The sleigh may be lifted into place using a boom arm or other rigged lifting arrangement and set onto a crane mat or similar external support structure. Cables entering the tower region are managed to avoid pinching during placement.

The sleigh is aligned so that its pins or interface features register with corresponding portions of the tower base or doorway. When a locking pin or access restraint is removed, a barrier such as a chain may be used to prevent unauthorized entry and preserve a controlled work zone.

The sleigh provides a guided transfer path between the exterior staging area and the tower interior. In representative embodiments, the sleigh may telescope or extend to support cabinet loading and controlled translation into the doorway region.

10.6 Cabinet movement into the tower

A cabinet such as the PDC or CFC is prepared for movement by attaching rigging and, where appropriate, coupling the cabinet to a lifting beam and to an external handling device such as a telehandler. The cabinet may be initially secured on the sleigh using straps or similar restraints. Such restraints are removed or loosened prior to rendering the cabinet into the tower.

During inward movement, the top or front region of the cabinet may be attached to a lifting beam or hoist arrangement, while the side or back region is controlled by the telehandler or comparable external equipment. The telehandler may pull the cabinet inward until a maximum slide extension is reached, while an internal hoist supplies controlled slack and vertical support. In some implementations, the intended movement at this stage is substantially horizontal.

If the slide or cabinet base interferes with the doorway, front jacks may be adjusted to raise the slide structure and maintain a suitable transfer angle. Constant communication may be maintained between personnel inside and outside the tower, particularly because the door region may also be the primary emergency egress path.

The CFC may require additional pulling assistance into final installed position. The optional pulling system may therefore be used where native structural features do not permit direct final positioning. Custom cribbing or protective covers, such as a resistor cover associated with the CFC, may be used as needed.

10.7 Cabinet-specific variations

Different cabinet types may follow slightly different installation paths.

For the PDC and CFC, the cabinet may be translated along the sleigh and then pulled or rendered into the tower using coordinated telehandler and hoist control.

For the CBC and MCC, at least two installation options may be used. In one option, the slide-extension step may be omitted, and after rerigging on the sleigh the cabinet is lifted inward and rendered using the hoist and telehandler. In another option, a process similar to the PDC and CFC is followed, except that the slide is not extended fully in order to avoid collision with an already installed CFC or other obstruction. Cabinets may be loosely bolted together before final bolting to the platform.

10.8 Lift beam and restoration

Following cabinet placement, auxiliary tooling may be removed. This may include removal of the sleigh, crane mat, optional pulling system, and lift beam. A converter lift beam assembly may also be used during the overall cabinet installation sequence. Fan installation or related component attachment may follow according to the applicable mechanical installation manual.

After cabinet installation, the turbine is restored. Restoration may include completion of the tower-door retrofit, preparation for converter reconnection, and cabinet reassembly or reconnection according to applicable reassembly procedures.

11. Advantages

The disclosed system and method provide several technical and operational advantages.

- First, the approach enables installation of large converter-related cabinets through an existing tower door opening, avoiding or reducing the need for more invasive access methods.
- Second, use of a sleigh or guided slide structure provides a controlled path for cabinet transfer between exterior handling equipment and the turbine interior.
- Third, platform reinforcement, temporary panels, and wear plates allow cabinet movement in areas that might otherwise be structurally unsuitable or discontinuous.
- Fourth, the coordinated use of internal hoisting and external rendering equipment improves cabinet stability and handling precision during transfer.
- Fifth, the optional pulling system provides a solution for towers lacking built-in pulling features, thereby improving repeatability across different turbine conditions.

- Sixth, cabinet-specific movement strategies allow accommodation of different module geometries and installation sequences, including situations in which previously installed cabinets restrict slide travel.
- Seventh, the method supports repower efficiency by enabling modular replacement and staged installation of converter subsystems inside the tower.

12. Example Embodiments

Example Embodiment 1

A method of installing a converter filter cabinet into a wind turbine tower includes measuring a tower door for compatibility, reinforcing an internal platform near the door with jacks, covering platform openings with temporary panels, positioning a telescopic sleigh on a crane mat aligned with the tower doorway, attaching the cabinet to rigging and a lift arrangement, moving the cabinet onto the sleigh, and coordinating an external telehandler with an internal hoist to move the cabinet through the door and into position.

Example Embodiment 2

A system for through-door converter installation includes a sleigh having a guided transfer surface, a crane mat supporting the sleigh outside the tower, temporary floor panels inside the tower, one or more support jacks beneath the internal platform, a portable or temporary hoist, rigging hardware sized to the cabinet type, and an optional pulling system attachable to foundation studs opposite the door.

Example Embodiment 3

A method of installing multiple cabinets includes first moving a PDC through the tower door using the sleigh and coordinated lifting, then moving a CFC using a similar process and optionally using a pulling system for final placement, and subsequently moving a CBC and an MCC using either a reduced-extension slide sequence or a rerigging-and-rendering sequence to avoid interference with previously installed cabinets.

Example Embodiment 4

A cabinet transfer method includes coupling a first portion of a cabinet to a lifting beam and a second portion of the cabinet to an external vehicle, translating the cabinet inward while the external vehicle provides horizontal pulling force and the internal hoist provides controlled slack and support, and adjusting front jacks if the slide structure contacts the door threshold.

Example Embodiment 5

A repower method includes installing converter cabinets through a tower door using the disclosed tooling arrangement, removing the tooling after placement, installing an associated converter fan, completing a tower-door retrofit configuration, and preparing the turbine for reconnection of the converter system.

13. Industrial Applicability

The disclosure is applicable to utility-scale wind turbines undergoing repower, retrofit, converter replacement, control-system modernization, or major electrical cabinet service. The methods are particularly useful where access into the tower is constrained and where heavy modular cabinets must be introduced without extensive structural disassembly.

The disclosed system may be applied by field service teams, repower contractors, OEM service organizations, and maintenance providers. It is useful across turbine fleets where tower-door dimensions, platform configurations, and internal cabinet layouts create handling constraints. The methods may also be adapted to analogous installations involving other tower-based industrial electrical modules that must be moved through limited-access openings.

14. Variations and Alternatives

Various changes may be made without departing from the general principles of the disclosure.

The sleigh may have different lengths, telescoping features, counterweight arrangements, or alignment interfaces depending on tower geometry.

The external handling equipment may be a telehandler, forklift, crane-assisted boom arrangement, or another mobile lifting system capable of controlled rendering.

The internal hoist may be a portable electric hoist, chain hoist, temporary tower hoist, or another lifting device suitable for the intended load and clearance envelope.

Support tooling may vary, including different jack types, panel materials, slide plates, cribbing arrangements, or attachment mechanisms.

The optional pulling system may be mounted using different structural interfaces and may be omitted where the tower includes integrated pulling features or where cabinet geometry does not require final assisted translation.

Different cabinet modules may be installed in different orders depending on turbine architecture, cabinet dimensions, internal obstructions, and reassembly strategy.

Although the disclosure is described in the context of wind turbine converter cabinets, the same general installation principles may be used for other modular electrical or electromechanical units introduced through constrained industrial access openings.

15. Conclusion

The present disclosure describes a practical and repeatable through-door installation system and method for modular converter equipment in wind turbine repower applications. By combining tower preparation, platform reinforcement, temporary access-surface creation, aligned sleigh positioning, coordinated internal and external lifting, and cabinet-specific movement strategies, the disclosed approach enables efficient transfer of large cabinets through a constrained tower door and into installed positions within the tower. The result is a field-deployable technical solution that improves serviceability, supports repower execution, and accommodates installation constraints commonly encountered in wind turbine retrofit operations.

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