

AN013 – Cooling Tower Defrosting with PLC

1. AN013 – Cooling Tower Defrosting with PLC

1.1. Disclaimer: Cooling Tower Defrosting with PLC

While every effort has been made to ensure the accuracy and completeness of the information contained in these application notes, SmartD makes no warranty, expressed or implied, including warranties of merchantability or fitness for a particular purpose. In no event will SmartD be liable to any party for any direct, indirect, special, or other consequential damages for any use of these application notes.

The user must exercise caution and follow all safety protocols when working with VFDs. This includes but is not limited to, wearing appropriate personal protective equipment (PPE), disconnecting power before working on equipment, and adhering to all applicable local and national electrical codes.

These application notes should not be used as a substitute for professional engineering advice, inspection, or consultation. The user is solely responsible for ensuring that any practices, installations, or actions taken based on these application notes meet all safety and operational requirements.

By using these application notes, the user agrees to indemnify and hold harmless SmartD from and against all losses, expenses, damages, and costs, including reasonable attorneys' fees, resulting from any violation of this disclaimer or any activity related to the user's account (including negligent or wrongful conduct) by the user or any other person accessing these application notes using the user's account.

SmartD reserves the right to make changes to these application notes at any time without notice. It is the user's responsibility to ensure they are following the most recent version of these application notes.

1.2. Cooling Tower Defrosting Application

Application Overview

Cooling towers operating in **cold or subfreezing climates** are prone to **ice accumulation** on key components such as fan blades, louvers, fill, and drift eliminators. When ambient temperatures fall below freezing, **moisture in the air condenses and freezes** on these surfaces, progressively restricting airflow and reducing the overall heat exchange efficiency of the system.

If left unmitigated, this ice buildup can lead to **mechanical imbalance, vibration, increased power consumption**, and even **severe damage** to the fan, gearbox, or support structure. Effective defrosting is therefore critical to maintaining both **cooling performance** and **equipment longevity** during winter operation.

Fundamentals of Frosting and Defrosting

In air-cooled or evaporative cooling towers, **ice formation** occurs when the operating temperature drops below 0 °C and **moisture in the airstream freezes on the evaporative surfaces**.

This layer of ice acts as a **poor heat conductor**, creating a barrier that reduces heat transfer and impedes the cooling effect of the tower.

If ice continues to accumulate, the airflow resistance increases, water distribution becomes uneven, and the tower's thermal performance declines significantly.

Defrosting restores normal operation by removing this ice layer and re-establishing the designed heat transfer capacity.

Defrosting Methods

Defrosting methods for cooling towers typically combine **mechanical airflow reversal** and, in some cases, **hot water flow**. These approaches are designed to safely melt or shed ice while minimizing stress on the fan and structure.

Fan reversal:

For **induced draft towers**, reversing the fan direction is one of the most effective methods. The procedure involves:

- Stopping the fan before switching direction to prevent mechanical shock to the drivetrain and avoid current spikes that could damage motor windings or the VFD.
- Operating in reverse at **low speed** (typically less than 50 % of rated speed) to prevent ice accumulation on the fan itself while generating sufficient airflow for defrosting. This speed range balances defrosting effectiveness with mechanical safety and energy efficiency.
- Running the fan in reverse for **short cycles** (15–20 minutes every 2–3 hours) as needed during cold periods. The frequency and duration should be adjusted based on ambient temperature and observed ice accumulation rates.

In reverse mode, warm air from the tower basin rises through the fill and louvers, melting accumulated ice.

Manual systems require careful operator attention, while automated systems can manage the cycle safely via the VFD and PLC.

Water bypass/ hot water flow:

In **crossflow towers, hot water circulation** can accelerate defrosting by transferring heat directly to frozen areas. Hot water can be distributed through the fill to melt ice on structural supports and louvers. When using this method:

- Stop the fan before initiating hot water flow to ensure even heat distribution and prevent thermal shock to ice-covered components.
- Ensure bypass valves are not open simultaneously with riser valves to prevent thermal shocks or overflow conditions. Rapid temperature changes can crack structural materials and create dangerous operating conditions
- If icing is severe, the tower may need to operate temporarily **without the fan** until the ice has melted.

Automatic defrosting systems:

Modern systems often integrate **automatic defrost control** through a **PLC**. This controller manages defrosting cycles via **time-delay logic** or **temperature-based triggers**, reversing each fan sequentially or individually based on real-time conditions. The system can extend defrost periods or repeat cycles automatically, reducing operator involvement and improving system reliability.

Key Benefits of Defrosting

Implementing an automated or controlled defrost strategy provides multiple operational and maintenance advantages:

- **Prevent ice buildup** on blades, louvers, and drift eliminators.
- **Reduce vibration and mechanical stress** during cold starts.
- **Avoid costly maintenance and unscheduled downtime** due to frozen equipment.
- **Eliminate the need for additional heating systems** or manual ice removal.
- **Enable fully automatic defrost cycles** controlled by simple digital inputs.
- **Improves safety and reliability** by maintaining balanced airflow and consistent heat exchange performance.

Automatic Defrosting System with a PLC and the Clean Power VFD

This application note proposes an **automatic defrosting architecture** that integrates a **PLC** and the **Clean Power VFD** to achieve reliable, scheduled, and energy-efficient defrosting cycles.

By briefly running the fan in the reverse direction at a low speed, warm air from the tower basin is drawn upward through the fan blades, melting accumulated ice without requiring external heating elements or manual intervention. This controlled reverse airflow accelerates thawing, reduces downtime, and helps maintain the mechanical integrity of the cooling tower assembly.

Schedule in the PLC

The **PLC** manages the **defrosting sequence and timing** for each cooling tower fan.

- The PLC's internal clock or temperature-based logic triggers defrost intervals based on ambient conditions and operational history.
- It sends **2-wire control signals** to the Clean Power VFD via digital inputs:
 - **DI3 (Run Forward)** for cooling mode
 - **DI4 (Run Reverse)** for defrost mode
- Each fan can be sequenced independently or in groups, with **adjustable cycle durations** (e.g., 15 min defrost every 3 h).
- The PLC can also lock out reverse operation when specific safety or process interlocks are active (e.g., pump off, low ambient airflow)

Clean Power VFD configuration for Safe Direction Change:

The **Clean Power VFD** incorporates built-in functions that make direction control safe and smooth:

- Reverse Operation Allow, permits controlled reverse rotation of the motor ensuring the VFD is configured to handle bidirectional operation without fault conditions.
- Seamless Direction Change, ensures torque and current are balanced during the transition, avoiding mechanical shocks that could damage gearboxes, couplings, or fan assemblies. This feature manages deceleration, zero-speed crossing, and acceleration in a controlled manner.
- Spinning Direction Priority, guarantees that defrost mode overrides normal cooling when both signals are active, preventing conflicting commands and ensuring the system always responds correctly to defrost triggers.

Together, these native features enable **safe, automatic, and seamless transitions** between cooling and defrosting without external hardware interlocks or additional programming.

During the defrost cycle, the fan operates in reverse at a **reduced frequency (low speed)**, allowing **warm, moist air** to flow upward and melt the ice. Once the defrost duration ends, the VFD smoothly returns the fan to forward operation. This approach minimizes downtime, conserves energy, and extends both mechanical and electrical component lifetimes.

System Benefits Summary

By combining the **Clean Power VFD's native motor control features** with a **PLC-based scheduling system**, operators gain an efficient, automated solution for cooling tower defrosting that ensures:

- Continuous reliability in subfreezing conditions
- Reduced manual intervention and labor costs



- Optimized thermal and mechanical performance
- Safe, repeatable transitions between operational modes
- Extended equipment lifespan through reduced mechanical stress
- Energy efficiency through optimized defrost cycles

.Compliance with safety falls under the user's responsibility not VFD manufacturer.

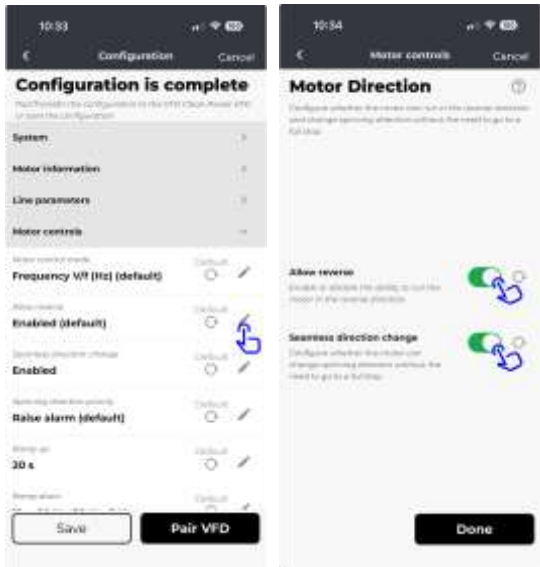
1.3. Implementation Guide: Cooling Tower Defrosting with a PLC

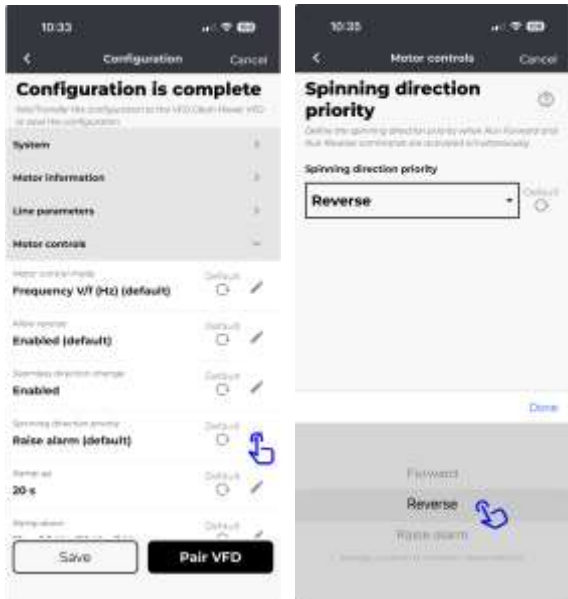
Software Compatibility

Please make sure to update your Clean Power VFD's firmware to version 2024.17.01 or later to enable the required features for the Cooling Tower Defrosting application

You can find the link to download the firmware in the latest release notes on the SmartD Help Center.

Step-by-step configuration

Configuration	Description
	Allow to control the motor in reverse direction and enable seamless direction change • Access the Advanced Configuration in the mobile app • Expand the Motor controls chapter • Click on the pencil of the Allow Reverse feature • Click on the Allow reverse switch to enable it • Click on the Seamless direction change switch to enable it • Click on Done

Configuration	Description
	Set spinning direction priority on reverse when both Run Forward and Run Reverse are simultaneously active - Click on the pencil of the Spinning direction priority feature - Click on the Spinning direction priority drop-down menu - Scroll up or down to select Reverse and click on Done - Click on Done
- Click on Save - Click on Transfer or Pair to connect and transfer the configuration to the VFD	

Clean Power VFD Configuration Summary

I/Os Configuration

Digital Inputs

DI	Function	Trigger type	Debounce delay
DI3	Run forward (2 wires)	High	0.2s
DI4	Run Reverse (2 wires)	High	0.2s

Relays

Relay	Function	Default coil state
R1	Any alarm above minor	Energized
R2	Ready-to-run	De-energized
R3	Motor running	De-energized

Analog Inputs

AI	Function	Mode
AI1	Set motor frequency	4-20mA curve: 4mA for 0.1 Hz and 20mA for 60 Hz

Analog Outputs

AQ	Function	Mode
AQ1	Motor frequency (Hz)	0-10V curve: 0V for 1Hz and 10V for 60Hz
AQ2	Motor current RMS (A)	4..20mA curve: 4mA for 0A and 20mA for the motor's nominal current

Remote Control

Parameter	Value	Notes
Remote source 1	I/Os	Using DI and AI for motor control
Remote source 2	Undefined	No Modbus TCP or BACnet IP
Source selection	Remote source 1	

Validation Procedure

This section describes the recommended steps to validate the correct operation of the **cooling tower defrosting system** using a **PLC** and the **Clean Power VFD**.

The validation process is divided into two phases:

1. Functional validation of I/O logic and VFD configuration without PLC scheduling (manual verification).
2. Full system validation with the PLC schedule activated (automatic sequencing).

Phase 1 – Validation without PLC Schedule (Manual Operation)

This first step verifies the wiring, I/O mapping, and Clean Power VFD control functions before introducing the PLC schedule.

It ensures that all commands, direction changes, and interlocks work safely under manual control.

Step 1 – Preparation

- Verify all electrical connections between the **PLC, Clean Power VFD**, and **motor**.
- Confirm the following I/O assignments:
 - **DI3**: Run Forward (Cooling mode)
 - **DI4**: Run Reverse (Defrost mode)
 - **DI1**: Reset Lockout
 - **AI1**: Frequency reference (0–10 V or 4–20 mA)
- Check the motor rotation direction at low speed to ensure forward and reverse modes are correctly wired.
- Make sure all mechanical guards and fan safety interlocks are in place.

Step 2 – Test Forward Operation (Cooling Mode)

- Using the PLC or hardwired test switch, set **DI3 = High** and ensure **DI4 = Low**.
- Observe that the VFD starts the fan motor in the forward direction.
- Confirm that the frequency reference from **AI1** correctly adjusts motor speed.
- Check the fan's airflow direction and mechanical stability.

Step 3 – Test Reverse Operation (Defrost Mode)

- Stop the motor and allow it to decelerate to zero speed.
- Set **DI4 = High** and **DI3 = Low**.
- Confirm that the **VFD reverses the motor** rotation smoothly.
- Verify the **Seamless Direction Change** feature functions correctly — no torque spikes or faults.
- Run the fan in reverse for a short duration (e.g., 3–5 minutes at 30–40 Hz).
- Observe air being drawn **upward through the tower fill**, simulating the defrosting effect.

Step 4 – Reverse Direction Priority Verification

- Validate that if both **DI3 and DI4** are high simultaneously, **Reverse Priority** ensures the VFD runs in reverse mode.

Step 5 – Functional Review

- Document current direction, speed, and airflow readings.
- Verify that defrost mode operation can be safely initiated and stopped without errors.
- Once manual validation is complete, disable test switches and return the system to PLC control.

Phase 2 – Validation with PLC Schedule (Automatic Defrost Operation)

After confirming manual operation, validate the automatic defrost sequence using the **PLC's programmed schedule**.

Step 1 – Review PLC Schedule Configuration

- Confirm the defrost schedule logic:
 - Defrost cycle frequency (e.g., every 3 hours).
 - Duration (e.g., 15 minutes reverse run).
 - Sequence (single fan or multiple fans in staggered timing).
- Verify that safety interlocks are implemented in the PLC (e.g., tower pump running, temperature threshold, or low-ambient lockout).

Step 2 – Enable PLC Control

- Put the VFD into **Remote Source 1: I/O control** mode.
- Enable PLC outputs to control **DI3 (Forward)** and **DI4 (Reverse)**.
- Start the cooling tower system under normal operation (forward cooling).

Step 3 – Observe Scheduled Transition

- Wait for the PLC's first defrost trigger or manually force the schedule event.
- Confirm that the PLC sends **DI3 = Low, DI4 = High**, initiating reverse rotation.
- Observe the VFD's smooth transition (no trip or overcurrent).
- Measure fan speed during defrost — it should remain below 50 % rated frequency.
- After the scheduled defrost time, confirm that the PLC reverts control to **Forward Mode (DI3 = High, DI4 = Low)**.
- Check for seamless transition and stable operation.

Step 4 – Validate Logging and Feedback

- Ensure that the PLC correctly logs each defrost event and duration.
- Monitor feedback signals (VFD run status, alarms, ready state).
- Verify that the defrost cycle can be overridden manually if needed.

Step 5 – Final System Test

- Run the system through several complete cooling–defrost cycles.
- Confirm proper timing, airflow reversal, and restoration of cooling mode.

- Verify the **mechanical stability** of fan blades and gearboxes during repeated reversals.
- Document and save the Clean Power VFD configuration.
- Review energy consumption and ensure temperature/icing conditions are adequately mitigated.

Phase 2 – Validation with PLC Schedule (Automatic Defrost Operation)

2. Manual control and override

Manual Control and Override

While the system is designed for automatic operation, manual control and override capabilities are essential for commissioning, troubleshooting, and emergency situations.

A selector switch and a timer should be added in parallel to the PLC output that commands the reverse operation of the VFD (defrosting)

- **Local manual control** at the VFD or control panel to directly command forward or reverse operation independent of the PLC schedule

Manual Defrost Initiation

Operators should be able to manually trigger a defrost cycle when:

- Visual inspection reveals ice accumulation between scheduled cycles
- Vibration or noise indicates ice loading on fan blades
- Performance monitoring shows reduced airflow or heat exchange efficiency
- Weather conditions change rapidly requiring more frequent defrosting

Procedure for manual defrost:

1. Verify the tower is in a safe operating condition (pumps running, no active alarms)
2. Initiate manual defrost command through selector switch
3. Confirm fan transitions to reverse operation at reduced speed
4. Monitor defrost duration (typically 15-20 minutes or until ice is cleared)
5. Return to automatic mode operation
6. Log the manual intervention in the maintenance record

Override Safety Considerations

Manual override functions must be designed to:

- Respect critical safety interlocks (emergency stops, vibration limits, etc.)
- Prevent simultaneous forward and reverse commands from different sources
- Require positive operator acknowledgment before executing direction changes
- the added timer must be used to prevent indefinite manual operation and automatically revert to scheduled operation after a defined period or operator reset

3. Defrosting Troubleshooting Guide

Ice continues to accumulate despite defrost cycles:

- Increase defrost frequency or duration
- Verify reverse airflow is sufficient (check fan speed settings)
- Inspect for blockages preventing warm air circulation
- Consider supplementing with hot water flow method

Excessive vibration during direction changes:

- Verify VFD deceleration/acceleration ramps are properly configured
- Check for mechanical imbalance or existing ice accumulation
- Ensure fan is fully stopped before direction change

VFD faults during reverse operation:

- Confirm "Reverse Operation Allow" is enabled in VFD parameters
- Check for overcurrent conditions (reduce reverse speed if necessary)
- Verify wiring and digital input configuration