System set-up and operation of NV Embedded® – Indoor Climate Control

1. General

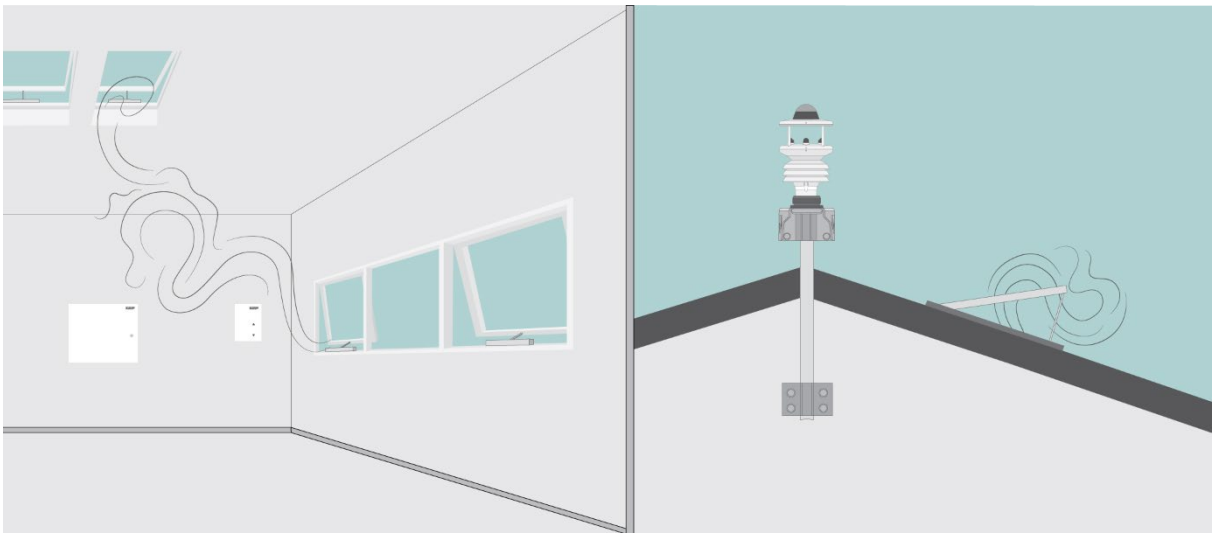
1.1 NV Embedded® is an indoor climate control solution developed by WindowMaster to optimize the use of natural and mixed-mode ventilation. The intelligent natural ventilation logic is embedded into the WindowMaster MotorControllers and has been developed and optimized since 1990. The control and strategies are therefore effectively adapted to knowledge about human comfort achieved by first-hand experience from more than one thousand projects worldwide.

The control sequences of NV Embedded® are designed to very accurately regulate the operable windows based on indoor and outdoor conditions to achieve a great air quality as well as thermal comfort. The millimeter precision of MotorLink® combined with the intelligence of NV Embedded® can greatly extend the annual number of hours where Natural Ventilation can be used to reduce HVAC energy consumption.

1.2 A building controlled by NV Embedded® is divided into zones that are independently controlled. Larger ventilated areas can be divided into multiple zones if needed.

1.3 The NV Embedded® solution requires the following equipment:

1. Window Actuators
2. MotorControllers and/or CompactSmoke™ panels
3. Temperature and CO_2 sensors
4. Weather station
5. Manual keypads (optional)



1.4 The NV Embedded® solution can control the heating and the mechanical ventilation systems, in conjunction with the natural ventilation, to achieve an optimal indoor climate in the building. Additionally NV Embedded® can also control solar shading, please contact us for more information about control of solar shading in NV Embedded® solutions.

1.5 A NV Embedded® solution can include either MotorControllers or CompactSmoke™ panels, or a combination thereof. Please contact us for information about when and how NV Embedded® solutions can include smoke panels.

2. System setup

2.1 Example of a NV Embedded® solution.

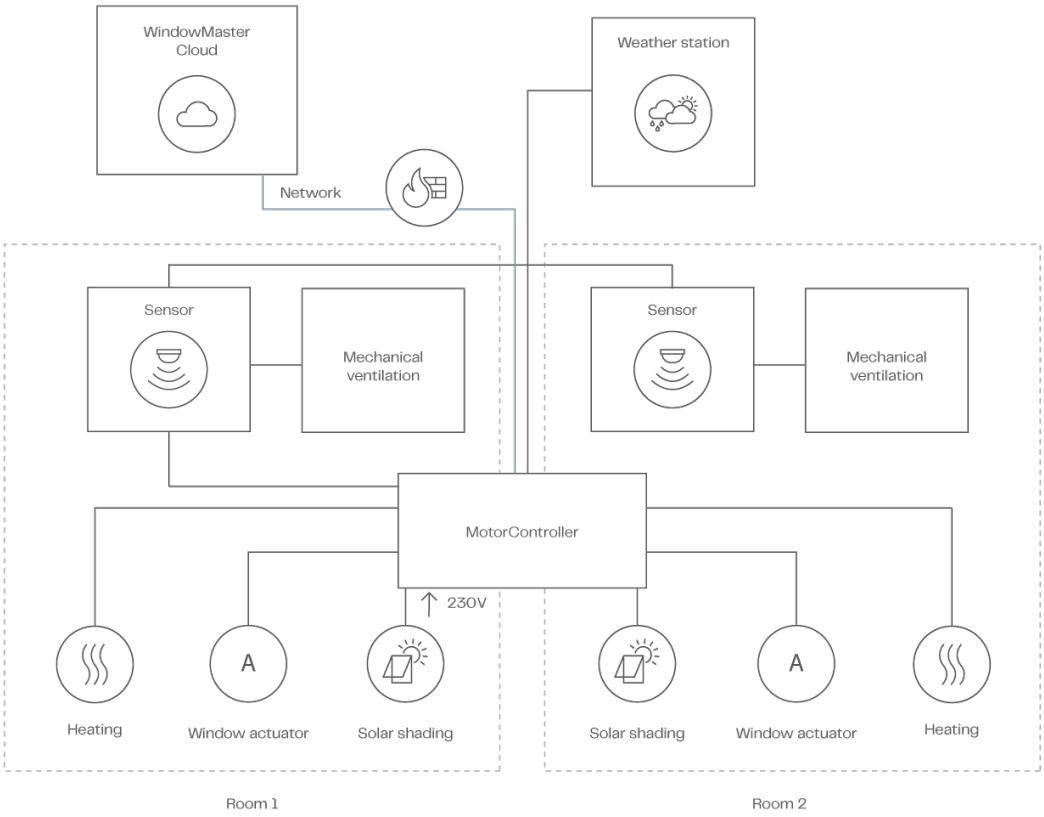


Figure 1 – Example of the system setup for a NV Embedded® solution.

3. Sensors placement

3.1.1. At least one sensor measuring internal CO_2, temperature and relative humidity levels shall be positioned in each ventilated zone to regulate the operable window

automatically. The sensor should be placed to avoid direct sources of inlet air, sunlight and CO_2 sources.

3.1.2. Multiple sensors can be placed in one ventilated zone if needed. The NV Embedded® system will use either an average value or a min/max value from the sensors to operate the windows.

3.1.3. When running as a stand-alone system NV Embedded® uses its own sensors. However, NV Embedded® can be configured to receive sensor data from other systems in the building over field-bus communication. See paragraph 4.

3.1.4. NV Embedded® uses a weather station to measure outside air temperature, precipitation, wind speed and wind direction. The weather station should be positioned in a favorable location at least 6 ft over the highest point of the roof.

4. Field-bus communication

4.1 NV Embedded® functions either as a stand-alone system or as an integrated part of a larger BMS.

4.1.1. As a standalone system, NV Embedded® will not need any communication protocol.

4.1.2. As an integrated part of a BMS, NV Embedded® can receive data from the BMS and control the operable windows based on these. It can also make feedback data available for the BMS system.

4.1.3. NV Embedded® can communicate using the following protocols: KNX, BACnet MSTP, BACnet IP Modbus RTU and Modbus TCP.

4.1.4. NV Embedded® Implements BACnet Host and Modbus Host. It does not include Client communication functionality.

5. Data cloud and user interface

5.1 All data from the NV Embedded® system can be gathered and stored in a cloud solution. This includes data such as indoor and outdoor climate conditions and position of the windows (opening degree). It can also log data in relation to failure in the system.

5.1.1. The end-user has an App for iOS or Android available which can show log data from the past 24 hours in the relevant zones in relation to thermal comfort and air quality. It can also give users the ability to override the system and operate windows in their working area.

5.1.2. The facility managers have a more advanced Cloud based Dashboard program available in which they can monitor all the ventilated zones, give permission to the end users and access more historical data about the building from the cloud solution.

6. NV Embedded® control strategy

6.1 Building states

6.1.1. A building can be in 3 different states, allowing the system to react in different ways and different priorities in the indoor climate control.

6.1.2. In the 'Building Occupied' state – typically the working hours – the system prioritizes user comfort keeping Comfort temperatures and ensuring low CO_2 levels. The secured periods will also be related to night cooling which is mentioned later in this document.

6.1.3. In the 'Building Secured' state – typically outside working hours and during the weekend – the system priorities Energy savings, allowing for 'Standby or Night temperatures and eventually higher CO_2 levels during the winter period.

6.1.4. In the 'Building Occupied Secured' state different parts of the building can be controlled in different ways, for example when a cleaning crew is present in the building after working hours.

6.2 Window operation

6.2.1. The operable windows will be automatically controlled by the NV Embedded® system as default and can be overridden by the user for a defined period.

6.2.2. Automatic operation

6.2.2.1. The system uses algorithms to automatically regulate the position of operable windows, vents and dampers based on:

- temperature, CO_2 and humidity
- wind speed
- wind directions
- wind pressure coefficients (found by Computational Fluid Dynamics (CFD) simulations) (optionally)
- temperature difference between inside and outside.

6.2.2.2. The time interval for when the NV Embedded® system should reposition the windows will be set as default. However, if requested, it can be defined as a specific value.

6.2.2.3. At regular intervals, the sensors transmit the measured values for internal CO_2, temperature and relative humidity (RH) as well as the measurement readings from the weather station. If the changes in the measurement values are less than the specified limits, then NV Embedded® only performs new calculations and adjustments at the intervals indicated here. However, if the changes are larger than the specified limits, NV Embedded® will make an adjustment instantly.

6.2.2.4. The system will automatically define upper comfort limits based on the outdoor temperature. The comfort limit is based on the maximum allowable Air Change Per Hour (ACH) in the ventilated space. Figure 2 shows an example of the maximum ACH based on the outdoor

temperature. The limits shown in Figure 2 will based on experience usually achieve a good level of comfort, however, it will vary based on the type and size of the rooms as well as the geographic locations.

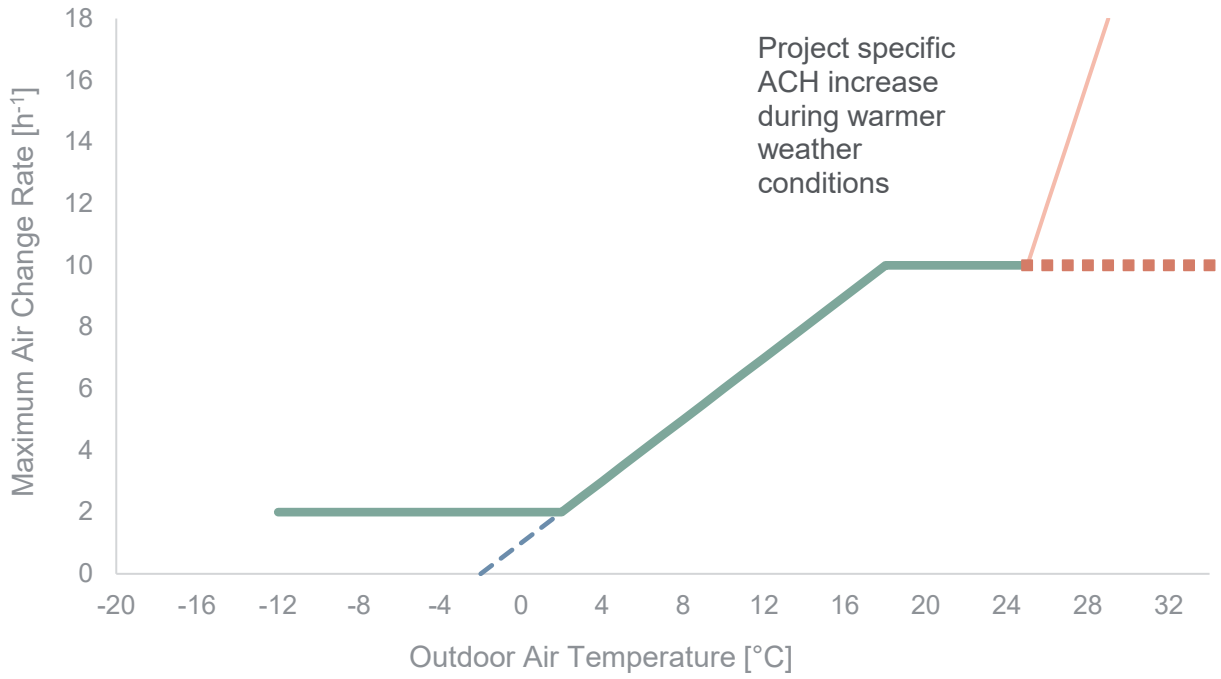


Figure 2 – The maximum allowable Air Change per Hour based on the Outdoor Air Temperature. Limiting the maximum ACH will provide a greater thermal comfort for the occupants.

6.2.3. Fixed ventilation schedule

The ventilation schedule can be fixed and can be set due to:

1. Specify the days to ventilate on a fixed schedule.
2. The fixed schedule can be defined to always take place or only when required.
3. The time of which the fixed venting should occur can be defined as well as the length of these.
4. It can be defined if the fixed ventilation occurs summer or winter mode.
5. It is also possible to define the opening degree of the operable windows in the fixed schedule.

6.2.4. Weather conditions

6.2.4.1. The maximum window position in a specific weather condition, like rain, can be pre-defined for the different building states.

1. Occupied building
2. Occupied building in secure mode
3. Unoccupied building
4. Rain
5. Wind velocity

6.2.5. Seasonal logic

6.2.5.1. The system will automatically change between summer and winter modes based on the outdoor temperature or a demand for heating/cooling in the ventilated zone. See Figure 3.

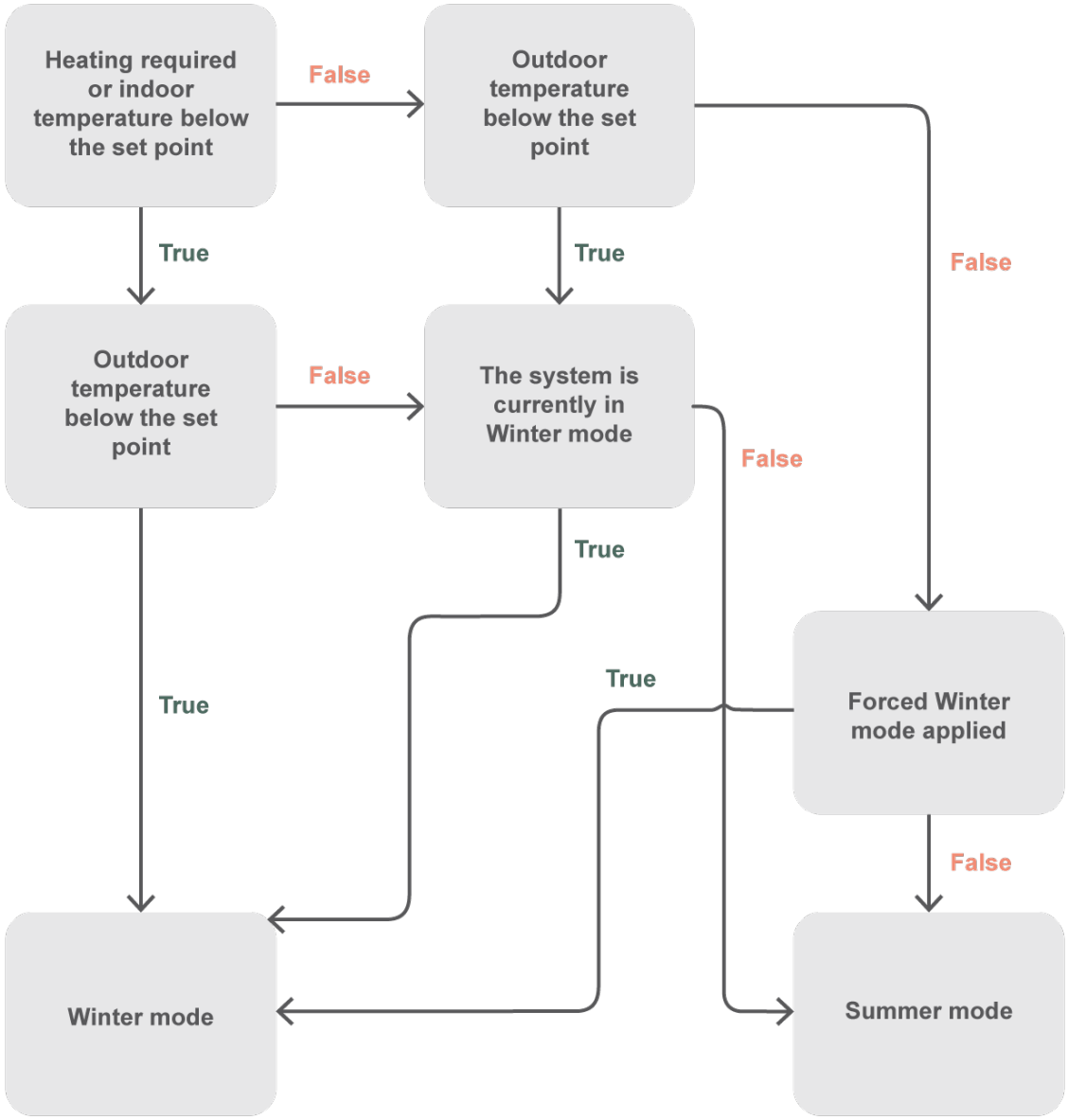


Figure 3 – Season logic of NV Embedded®

6.2.5.2. Forced winter mode happens if the system is told either manually or by the BMS to proceed into winter mode.

6.2.6. Summer mode

6.2.6.1. In summer mode, the automatically controlled operable windows will be regulated based on temperature control as default. However, the system will still account for factors such as air quality and humidity by regulating the temperature setpoint accordingly.

6.2.6.2. During temperature control, the windows will open based on the indoor temperature. However, the system will set and upper limit for the maximal allowable air change rate based on the outdoor temperature to ensure good comfort, as shown in paragraph 6.2.2.4.

6.2.6.3. The rate at which the operable windows are opened will depend on the applicable wind conditions (wind speed, wind direction and wind pressure coefficients). At higher wind speed the windows will open at a slower rate to avoid discomfort.

6.2.6.4. The windows will close at a fast rate as it is more important to quickly reduce the window opening to avoid discomfort.

6.2.6.5. In temperature-controlled ventilation mode, the NV Embedded® system is still accounting for the air quality (CO_2 and humidity) by reducing the temperature setpoint based on how much measured values for the CO_2 or humidity exceed the defined setpoints.

EX: Measured CO_2 content is 1000 → (1000 ppm – 800 ppm) x 0.005 K/ppm = 1K

6.2.6.6. A minimum allowable ventilation temperature threshold is defined. Despite high CO_2 and RH effects, the temperature setpoint never goes lower than this limit.

6.2.7. Winter mode

6.2.7.1. In winter mode, the ventilation will be regulated based on air quality. The system will by default employ a demand driven pulse ventilation. Pulse ventilation means that the windows are opened for a short period of time and then closed again. See example in Figure 4.

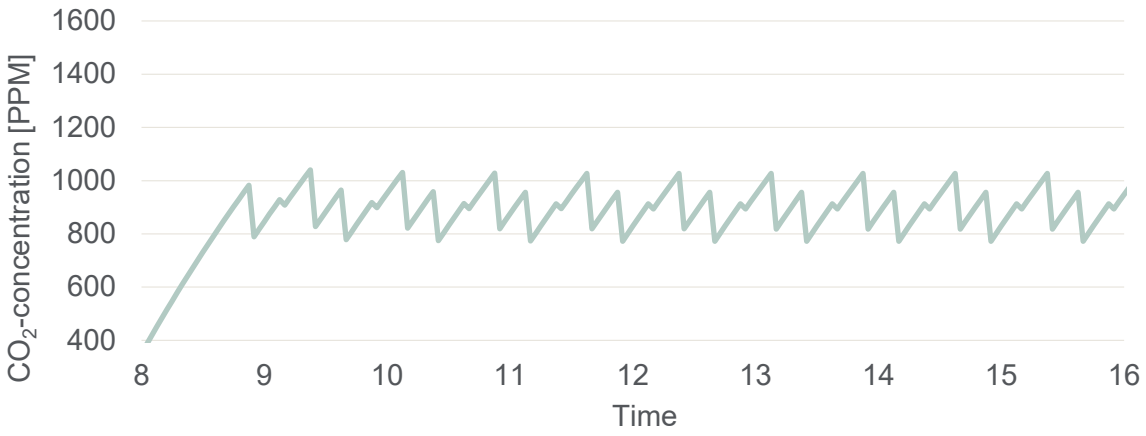


Figure 4 – Simplified illustration of demand driven pulse ventilation.

6.2.7.2. The demand driven pulse ventilation is performed when the CO_2 or humidity values exceeds the configured thresholds. The ventilation pulse duration and the interval between the pulses are calculated from the actual measured values and parameter settings. The maximum window opening is limited by the outdoor temperature and the wind speed. It should be considered, if a demand-driven pulse ventilation should be used in combination with ventilation on fixed schedule, as the two ventilation strategies are controlled entirely independent of each other.

6.2.7.3. If the temperature exceeds the defined threshold for ventilation the amount of ventilation is gradually increased. If the value is e.g. 0.2 1/K the ventilation will be at a maximum when the current temperature is 5 degrees higher than the set point.

6.2.7.4. Specify the maximum allowable temperature drop. If the temperature drops more than this value below the current set point the windows are closed completely in one step.

6.2.7.5. A maximum and minimum duration of the pulse ventilation during demand-driven pulse ventilation can be defined. The actual pulse ventilation duration is calculated from the measured values and thresholds for CO_2 and RH and influential parameters. If the desired CO_2 and RH level is reached before the ending of the max. pulse limit, the windows will close.

6.2.7.6. Trickle ventilation will start if the CO_2 level was not reduced below the CO_2 threshold after a specified number of pulses have been executed. Pulse ventilation will still continue (if not deactivated) and the trickle vent position will be the new minimum position for the pulse instead of completely closing the window.

6.2.7.7. Trinkle ventilation will not start if the indoor temperature is below the minimum temperature threshold for trinkle ventilation.

6.2.7.8. When Trickle ventilation is active the windows opening is between 0% and the ‘Max. opening during Trickle ventilation’ position of the Motor group the windows belong to. The actual opening corresponds to the percentage of the actual CO_2 level as calculated between the ‘CO_2 level for no Trickle’ to the ‘CO_2 level for full Trickle’.

6.2.8. Night cooling

6.2.8.1. The night cooling is connected to the secured building mode outside of occupied hours.

6.2.8.2. The night cooling is performed by defining setpoint-offsets for the summer mode. When the system enters ‘unoccupied mode’ outside the work hours, it will automatically activate the new setpoint generated by the defined offset to perform the night cooling.

1. Ex1: Base ventilation setpoint = 24 °C

   Night cooling setpoint = 24 °C – 4 °C = 20 °C

6.2.8.3. In the shoulder season, the system can be in winter mode during the night and summer mode during the day. This ensures that night cooling is not used during the night even though the system is in summer mode during the day.

6.2.8.4. As an integrated part of a BMS, NV Embedded® can also receive signal of when to night cool.

6.2.9. Manual operation

6.2.10. Users may be allowed to manually operate windows through either the NV Embedded® App for mobile devices or switch panels accessible in the ventilated zones.

6.2.11. After a defined period, the automatic system will take over again and regulate the operable openings based on the relevant conditions.

6.2.12. Motorized windows for manual control can either be controlled individually or grouped together in the ventilated zones.