Inverter Technology: Unlocking the Full Potential of Heat Pumps to Decarbonize the Northeast

Presented by Jon Hacker
for NESEA’s BuildingEnergy NYC 2022 Pre-Conference Webinars on September 9, 2022
Agenda

1. Introduction to Daikin
2. Inverter and Mechanical System Basics
3. Inverter Impact on Operation
4. Benefits to Society
5. Inverters Applied
Daikin Overview

95+ Years of History
Founded in 1924

Annual Sales of $21 BILLION

More than 100 global production bases for localized production

Business development in more than 160 countries

Company: Daikin Industries, Ltd.
Head Office: Osaka, Japan
Founded in 1924
Chairman of the Board: Noriyuki Inoue
President and CEO: Masanori Togawa
Employees: 84,870
Group Companies: 315

As of March 31, 2021
Daikin’s Core Competencies

① HEAT PUMP
Heat pump is energy saving technology that conveys heat without the need to generate heat.

② INVERTER
Inverter is energy saving technology that eliminates wasted operation in air conditioners by efficiently controlling motor speed.

③ REFRIGERANT
R-32 is a next generation refrigerant that efficiently carries heat and has lower environmental impact.

Comparison of Energy Consumption (example) *

<table>
<thead>
<tr>
<th></th>
<th>Non-Inverter Type Air Conditioner</th>
<th>Inverter Type Air Conditioner</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>42%</td>
<td></td>
</tr>
</tbody>
</table>

Saves 58%

* Energy consumption is calculated complying with JIS B8616:2015 for model SSR1C140BA (inverter) and equivalent non-inverter type air conditioners.

100 Year Global Warming Potential of Different Refrigerants *

- CO2
- R-32 (HFC)
- R-22 (HFC)
- R-410A (HFCG)
- R-11 (CF3)
- R-12 (CF2)
- R-23 (CF)

*Source: Values for 100 year global warming potential (GWP) from IPCC Fourth Assessment Report. Comparative 100 year GWP: HFC410A, 2,090; HFC32, 675
Daikin Group carries lineup meeting all types of needs including those for energy-savings, the environment, comfort, peace-of-mind, safety, and health.

Daikin Group Brands in North America:

- Residential AC
  - Room Air Conditioners
- Housing/Multi-Split Air Conditioners
- Unitary Air Conditioners
- VRV Systems
- Ventilators
- ACs for Facilities and Factories
- Control/Maintenance Systems
- Applied ACs
  - Centrifugal Chillers
  - Chillers
  - Air Handling Units
  - Fan Coil Units
- ACs for Small Shops and Offices
- Rooftops
- Air Purifiers
- Heating/Water Heaters
- Air Handling Units
- Fan Coil Units

Daikin Group Companies and Products
Sustainability at Daikin

**Daikin Environmental Vision 2050**
We will provide safe, healthy air environments while striving to reduce greenhouse gas emissions to net zero.

### Through products
- Increase energy efficiency of products
- Development and adoption of refrigerants with lower global warming potential
- Reduction of GHG throughout the entire product lifecycle including production

### Through solutions
- Use energy management to carry out efficient operation of buildings with centralized systems for energy efficiency and renewable energy
- Provision of energy services throughout the value chain

Reducing the remainder by:
- Switching, recovering, and reclaiming refrigerants
- Spreading use of heat pump space and water heaters
- Conducting renewable energy businesses
- Protecting forests
- Others

### Through the power of air
- **High Quality of Life**
  - Highly productive office environments
  - Enhance concentration
  - Improve quality of sleep
- **Healthy and Comfortable**
  - Reduce sleep disorders
  - Reduce stress
  - Provide consistent whole house room temperatures
- **Safe and Reliable**
  - Protect people’s health from air pollution
  - Reduce risk of infectious diseases
  - Prevent heatstroke

**Image: The power of air**
Agenda

1. Introduction to Daikin
2. Inverter and Mechanical System Basics
3. Inverter Impact on Operation
4. Benefits to Society
5. Inverters Applied
What is an Inverter?

- An Inverter is a technology that changes the power supply frequency provided by power companies into a desired frequency (Hertz)
- In heat pump and air conditioning equipment, inverters are applied to the compressor as that is the main energy consuming component
- When inverters are used in HVAC equipment, it can be referred to by many names:
  - Variable Capacity
  - Variable Speed
  - Inverter driven
  - Extended capacity
  - Extra performance
  - Extreme climate
  - Cold-Climate
Non-Inverter (single and two-stage) HVAC systems function like your car does in the city: Stop. Go. Stop. Go.

This causes your vehicle to work harder and use more resources to run, decreasing your overall MPG.

Inverter (variable-speed) HVAC systems function like your car does on the highway: You set the cruise control and go!

Cruise control allows you to match speed to road condition, boosting your overall MPG.
Heat Pump System Basic Operation

### COOLING MODE
- **Indoor Air**
- Cooled Indoor Air
- **Heat Rejected**

### HEATING MODE
- **Indoor Air**
- **Energy (Heat) Extracted**
- **Warmed Indoor Air**
1. Compressor
   The “heart” that pumps the refrigerant
   Found in the Outdoor unit

2. Reversing Valve
   Found in systems that provide both heating & cooling

3. Indoor Unit
   Also known as the evaporator or fan coil
   (acts like a condenser during heating cycle)

4. Expansion Valve
   Regulates the flow of refrigerant
   Found in either IDU or ODU

5. Outdoor Unit
   Also known as the Condensing unit
   (acts like an evaporator during heating cycle)
Heat Pumps are Not New

But Inverters in Residential Air Conditioners and Heat Pumps Is Relatively New in the US
Lots of Opportunity for Inverter Adoption in the US

Note: Residential air conditioners: Ductless air conditioners other than window and portable type products. Only in North America does the category include ducted air conditioners for residential use.

Source: Compiled by Daikin based on data from the Japan Refrigeration and Air Conditioning Industries Association
1. Introduction to Daikin
2. Inverter and Mechanical System Basics
3. Inverter Impact on Operation
4. Benefits to Society
5. Inverters Applied
Load Line to Modulating Zone

Single-Speed Delivered Capacities

- Cycling Line
- Single-Speed

Inverter Delivered Capacities

- Modulating Zone with Inverter

Load Line to Modulating Zone

- DZ16SA042 Capacity
- RZQ42 Minimum Capacity
- RZQ42 Maximum Capacity
More Heating Capacity Delivered with Inverter

Inverter Delivered Capacities

- DZ16SA042 Capacity
- RZQ42 Minimum Capacity
- RZQ42 Maximum Capacity
- DZ16SA060 Capacity

3.5 Ton Modulating Zone with Inverter

5.0 Ton Cycling Line
Single-Speed

3.5 Ton Cycling Line
Single-Speed

Outside Air Temperature (F)

Capacity (Btu/h)
Cycling to Modulating

**Inverter**

- Overcooling
- Poor temperature control
- Inefficient use of energy

**Graph**

- Temperature vs. Time
- Set Point
- Minimal temperature fluctuation
- Efficient use of energy

- Daikin Inverter AC
- Non-inverter AC
Cycling to Modulating: Trend Data

**Non-Inverter Unit**
- Outdoor temp: 32F
- Set Temp: 73F

**Inverter Unit**
- Outlet temp.
- Room temp.

- 19 Compressor Starts
- 6 Compressor Starts
Lower Frequency over Time Yield Energy Savings

Non-Inverter Unit

Inverter Unit

- Outlet temp
- Room Temp
- Energy-saving

Frequency of Compressor

Temperature F

Time [Hour]
Inverter Impact in Westchester County

**Single-Speed Compressor Design Example**

- DZ16SA042 Capacity
- Westchester, NY Heating Load Line

**Inverter Compressor Design Example**

- RZQ42 Minimum Capacity
- RZQ42 Maximum Capacity
- Westchester, NY Heating Load Line
Design Temp Extremes vs. Abundant Mild Temperatures

Westchester County

Heating Hours

Cooling Hours

Center of Temperature Bin (Degree F)

Annual Hours in Temperature Bin

Data Source: ASHRAE Weather Data Viewer Version 6.0
**EER**
- A peak cooling load metric, evaluates efficiency at 95°F (35°C) at nominal speed.
- EER is a valuable metric for utilities as it reduces electric system peak demand.
- According to the Electric Power Research Institute, “the link or EER and building performance is not straightforward”

**SEER**
- A seasonal cooling metric, that estimates efficiency over an entire cooling season.
- SEER is a valuable metric for consumers, as it relates to their energy consumption and costs.
- SEER considers that the efficiency of the equipment varies based on outdoor temperature.
- SEER is based on a lab testing and applies weather bin data to estimate energy-use over a cooling season.
More Inverter Benefits

- High Efficiency in Part-Load conditions.
- As room temperature nears set point, the capacity is automatically ‘throttled down’
- Better dehumidification, and fewer start/stop cycles.
- Power factor of near Unity
- Minimal locked rotor amps means less stress on windings
- No “light flicker” or “loud thud” when equipment is energized. It soft starts and stops.
- Better lubrication of compressor.
- System pressures increase gradually, reducing noise and stress on piping.
- Better dehumidification, and fewer start/stop cycles.
- As room temperature nears set point, the capacity is automatically ‘throttled down’
- Huge decrease in compressor energy consumption
1. Introduction to Daikin
2. Inverter and Mechanical System Basics
3. Inverter Impact on Operation
4. Benefits to Society
5. Inverters Applied
Feel the Difference

**UNCOMFORTABLE**
Room Temperature 77°
80%
86°F

**COMFORTABLE**
Room Temperature 77°
50%
104°F

Your Thermal Body Temperature
Hear the Difference

Without Inverter

73dB(a)**

With Inverter

57dB(a)

*Comparison of VRV LIFE™ outdoor unit to Daikin DZ14SA outdoor unit.

**Daikin DZ14SA
Efficient Electrified Heat Pumps in Cold Climates

AURORA: 2, 3, 4 zone multi-split
Up to 100% rated heating capacity at 5°F continuous operation to -13°F

“Sky-Air” Large capacity single split
Continuous operation to -4°F
Invest in Tomorrow, Today!
1. Introduction to Daikin
2. Inverter and Mechanical System Basics
3. Inverter Impact on Operation
4. Benefits to Society
5. Inverters Applied
Questions?

Jon Hacker
Director, Decarbonization & Efficiency
Daikin U.S. Corporation

Jon.Hacker@DaikinUS.com