ENGINEERING
TOMORROW

Case story | Optyma™ Plus INVERTER

Danfoss
Fixed Speed Scroll Technology vs. **Inverter Scroll Technology**

Electricity savings when comparing the two technologies

Study conducted in South Africa

Objective

Energy efficiency is swiftly becoming a key concern within the refrigeration and air-conditioning sector. In addition, power supply constraints in some parts of the world are putting an emphasis on expanding HVAC/R infrastructure using the same power supply.

The objective of this study by Danfoss South Africa was to test the energy-saving potential that could be realised by using variable speed technology, specifically focusing on scroll compressors. By quantifying the saving, one can then easily calculate the savings over the full lifecycle cost considering the initial capital outlay. Hopefully this proves that lifecycle cost outweighs initial capital outlay when using energy-saving technology.

In this study, a Danfoss fixed speed Optyma™ Slim Pack (114X7043 – OP-MPVE068) was tested against an Optyma™ Plus INVERTER (114X4334 – OP-MPPM044). The test was conducted over a period of three months, starting in February 2021 and concluding at the end of April of the same year. During this time, electricity consumption was the chief focus, with surrounding factors that could potentially influence results also being monitored.

Hypothesis

Recent Danfoss studies from Europe estimate that inverter technology could potentially lead to an energy saving of approximately 30 percent when compared to fixed speed technology. This, however, is averaged out taking factors into account such as:

- Design criteria;
- Ambient temperatures;
- Varying load conditions;
- Door openings;
- Products being stored; and more.

When looking at this, it was clear that claiming a blanket 30 percent saving was too vague and therefore needed further investigation. A local experimental site was therefore identified to conduct a practical test to verify the 30 percent energy saving claim.

Study

The study was conducted to physically measure the potential energy saving that could be expected from utilising inverter technology. This was done both theoretically, as well as physically, by setting up a practical experimental site.

Theoretical data

Based on the eventual design criteria, the following was considered:

Optyma™ Model	OP-MPVE068	OP-MPPM044	
Code	114X7043	114X4334	
Technology	Fixed speed scroll	Permanent magnet motor Inverter scroll	
Refrigerant	R507	R507	
Number of rooms	1	2	
Door opening frequency	Low	Medium	High
Products stored	Beverages	Bakery products	Mixed products
Expansion technology	Thermostatic	Thermostatic	Thermostatic
Evaporating temperature	+3 °C	-2 °C	-2 °C
Ambient temperature	26 °C	26 °C	26 °C
Eventual design capacity [2]	4.2 kW	1.8 kW	2.7 kW

Table 1 - Conditions of selection

[1] An ambient temperature was obtained by taking the average ambient temperature over the three-month span.
[2] Data extracted from Danfoss Coolselector2 using the abovementioned data.

Practical test

The initial design specification called for 100 percent capacity on both units, with the Inverter unit being slightly undersized (10 kW of cooling capacity with 9 kW capacity being delivered under a worst case scenario of -5 ^{0}C evaporating temperature with 43 ^{0}C ambient temperature). Further to this, selections were made taking worst case scenarios into account which, according to a rule of thumb, only occurs for two percent of the time throughout the year. It is derived as follows:

- South Africa typically experiences three warm months during the year (December, January and February).
- During these days, the highest temperatures were experienced for approximately two hours, depending on the specific day's weather.
- Taking both of these factors into account, an accurate assumption could be made that maximum temperatures would be experienced for 178 hours over a full year.
- This equates to two percent of a full year (Weather, 2021), meaning that Danfoss chose units to run at the design specification for this time only. For the remaining 98 percent of the time, there would be excess capacity due to an oversized design.

Results

Sizing factor

Condensing units are selected, taking worst case scenario into account, as already mentioned under heading 3.2. Units are therefore running at full capacity for two percent of the year. To calculate energy consumption over a period of time, we therefore have to compensate for this by calculating a Worst-Case Scenario Factor, WCSF.

Optyma™ model	OP-MPVE068	OP-MPPM044
Code	114X7043	114X4334
Technology	Fixed speed	Inverter
WCSF	3.05	2.83

Electricity consumption

After logging the accumulative kWh consumption of both units over a three-month period (see Appendix C, pg. 10), the following results could be reported:

Optyma™ model	OP-MPVE068	OP-MPPM044
Code	114X7043	114X4334
Technology	Fixed speed	Inverter
Acc kWh (5 Feb 2021 – 4 Apr 2021)	1 703.3 kWh	1 193.4 kWh
Daily average kWh	19.35 kWh	13.56 kWh
Actual annual extrapolated kWh	6 813.2 kWh	4 773.6 kWh
WCSF	3.05	2.83
Full size consumption	20 780.3 kWh	13 509.3 kWh
Capital cost factor 3	1	2

Analysis of results

Electricity savings were calculated as follows:

$$\% \text{ Saving} = \frac{\Delta \text{Consumption [kWh])}}{\text{Original consumption [kWh])}}$$

$$= \frac{(1703.3 - 1193.4)}{1703.3}$$

$$=29.94\%$$

However, once the adjusted size factor had been taken into account, annual saving were adjusted as below:

$$\% \text{ Saving} = \frac{\Delta \text{Consumption [kWh])}}{\text{Original consumption [kWh])}}$$

$$= \frac{(20780.3\text{-}13509.3)}{(1703.3)}$$

$$=34.99\%$$

Monetising

Looking at the results, it can be said with confidence that inverter scroll compressor technology would offer a significant saving compared to fixed speed scroll technology or similar. It is therefore possible to calculate a monetising factor by converting it to a non-dimensional value:

$$\% \text{ Saving} = \frac{\Delta \text{Consumption [kWh])}}{\text{Original consumption [kWh])}}$$

$$\% \text{ Saving} = \frac{(\Delta \text{Saving value})}{(\text{Original value})}$$

$$29.94\% = \frac{(1\text{-}x)}{1}$$

$$x = 1\text{-}0.2994$$
$$x = 1\text{-}0.7006$$
$$\approx 0.7$$

For every one unit (electricity consumption/cost) consumed/spent on the fixed speed unit, an equivalent 0.7 units are consumed/spent on the inverter unit. Factors that were not incorporated, but would significantly contribute to a further saving, include peak load demand during peak electricity periods, where one would pay for the highest peak load demand. Typically, this happens when fixed speed compressors start up and the amperage spikes for split seconds. This influence is neutralised using inverter technology by preventing this, and further reducing consumption due to actively adapting to cooling demand by speeding the compressor up and down, thereby varying the demand load. This is but one factor that could further increase direct electricity savings.

[3] Using the above monetising factor in conjunction with the cost factor (Table 3, page 4) a return on investment, specifically comparing these two units, can easily be calculated.

Further actions

Direct impact

Based on the results of this study, it is clear that when using basic technology, a saving could be realised by merely changing one element of the cycle. Further savings could hence be reached by potentially changing the following:

- Thermostatic expansion to electronically controlled expansion (Danfoss MSS* technology specifically).
- Implementing smart defrost cycles, including defrost on demand.
- Pulsing of fans during the off cycle, and more.

The inclusion of these additional features (normally already incorporated in the evaporator controller), a saving of approximately 40 percent can easily be realised, when comparing traditional technologies.
**Minimum stable signal, offering a further six to eight percent in electricity savings, depending on application.*

Indirect impacts

Putting the electricity saving aside, further savings and optimisation features to be gained by using this technology include:

- Increased food safety due to accurate suction control, which directly leads to an upsurge in food shelf life.
- Reduced sound levels (dB) due to compressor technology and EC fans.
- A smaller footprint – one unit to run several cold rooms, as it can adjust to load.
- Lower maintenance cost due to fewer components.
- Reduced complexity and capital cost on installation:
    - One condensing unit with two rooms, which leads to shorter pipe runs and less gas.
    - Less risk of leaks.

Conclusion

It can safely be said that a minimum of 30 percent in electricity savings could be realised in equally sized condensing units, when changing over from fixed speed scroll technology to inverter scroll technology. And this saving only increases as cooling circuits are added to the inverter condensing unit.
When looking at the expanded criteria, it is completely plausible to assume that the saving will most likely lead to a 40 percent saving in electricity when sizing the units correctly, and combining the inverter scroll technology with the appropriate energy-saving evaporator (MSS) controls.
Return on investment (ROI)/ total cost of ownership (TCO) will depend on the type of installation but can be easily calculated using the information outlined above and an escalation in electricity cost on an annual basis.

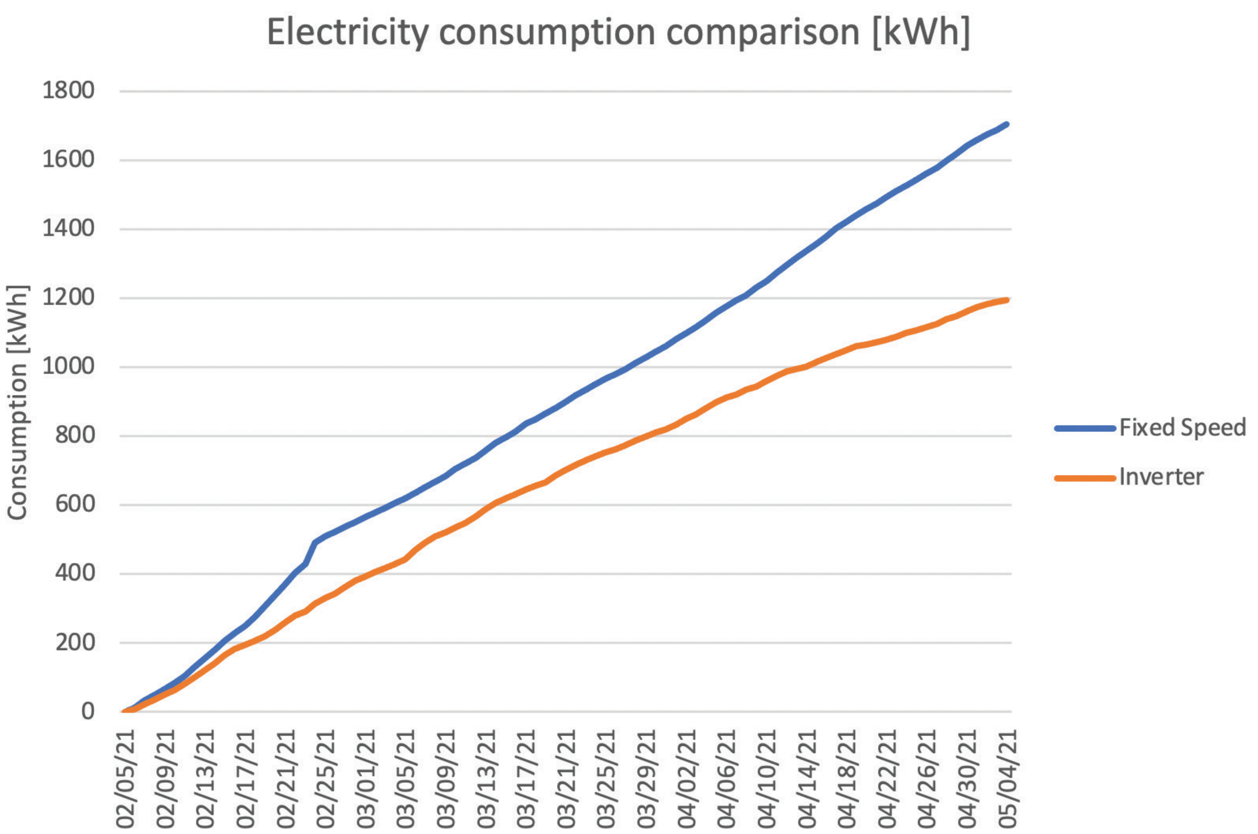
Bibliography

Weather. (2021, June 15). Retrieved from timeanddate.com:
https://www.timeanddate.com/weather/south-africa/vereeniging/historic?month=2&year=2020)

Appendix A
List of equipment used

No.	Description	Code number	Qty
1.	Optyma™ OP-MPVE068MLW04E 380V 3-ph	114X7043	1
2.	Optyma™ OP-MPPM044VVLP01 380V 3-ph	114X4334	1
3.	Wattnode energy meter	080Z2146	2
4.	Split core 50A CT		6
5.	AK-CC 550 (Fixed speed condenser monitoring)	084B8020	1
6.	EKC 302D Evaporator controllers	084B4164	3
7.	TES2 Thermostatic expansion valves orifice no 3	068Z3415	3
8.	Te2 Orifice 3	068-2006	3
9.	Solenoid valves	032F1204	3
10.	AK-SM 355	080Z2564	1
11.	4.4 kW blower coil		2
12.	8.3 kW blower coil		1

Appendix B
Electricity consumption results



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