Single versus three phase motors with a VSD

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A comparison between single phase motors and three phase motors with variable speed drives from a technical and commercial point of view.

Single phase motors are generally used on farms, office buildings and in residential applications where low output power is required and no three phase system is available.

However, with the ongoing improvement in technology and also cost reduction on small size variable speed drives (VSDs), three phase motors can now be used. You would still feed single phase to the drive, but would have a three phase voltage to feed the motor.

Single phase motors

Single phase motors are motors with a single winding and fed with a single phase voltage (see *Figure 1*).

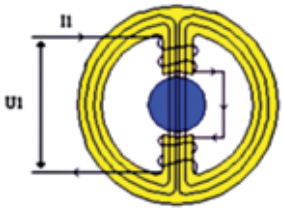

Figure 1: Single phase winding.

The variation of flux on the magnetic field at the stator will induce voltage or current on the rotor and an opposite magnetic field will be created, but the motor shaft will not rotate. Thus, on single phase motors, an auxiliary winding is used and mounted on the stator 90 degrees apart from the main winding to create a secondary magnetic field which will allow the motor shaft to rotate.

Abbreviations

DOL – Direct On Line
VSD – Variable Speed Drive

There are various arrangements that can be used but the most common design is the one that uses a starting capacitor or a starting and a run capacitor as per the diagrams on *Figures 2 and 3*.

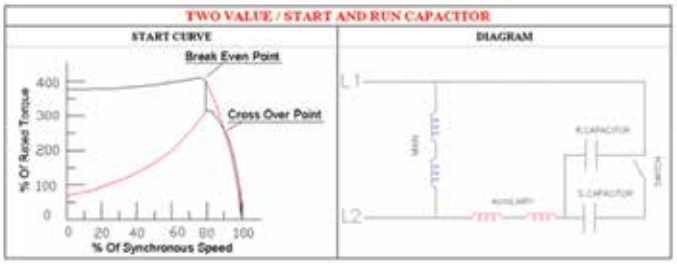

Figure 2: Diagram and starting curve for a single phase motor with start and run capacitors.

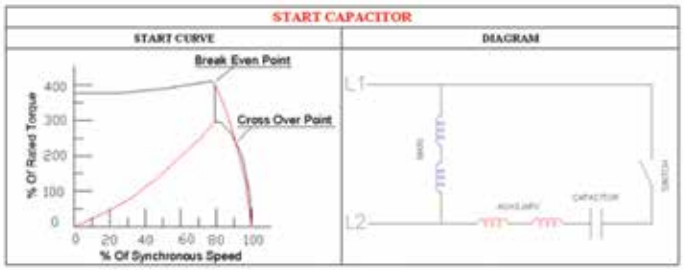

Figure 3: Diagram and starting curve for a single phase motor with start capacitor only.

Both are used in general applications and present high starting torque, with the run capacitor being added to improve the performance of the motor when running. In both cases, the motor is equipped with a centrifugal and a stationary switch which is normally closed. At start up, the auxiliary winding is then connected to the circuit and displaces the magnetic field, allowing the motor to turn. As soon as the motor gets to about 90% of the nominal speed, the switch opens disconnecting both the auxiliary winding and the starting capacitor from the circuit or, in the case where the motor also has a run capacitor, it disconnects the start capacitor from the circuit. A single phase motor would typically be started direct on line (DOL) (see *Figure 4*).

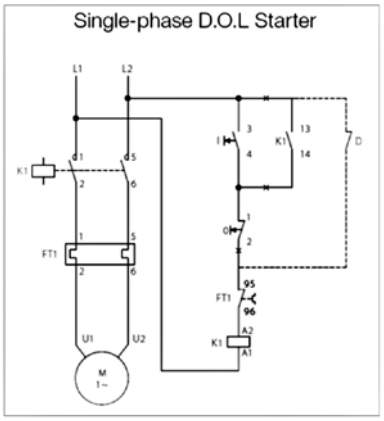

Figure 4: Diagram for a single phase direct on line starter.

Three phase motors running on VSD

Three phase motors are motors with three windings and fed with a three phase voltage (see *Figure 5*).

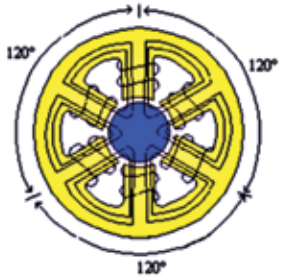

Figure 5: Three phase winding.

The variation of flux on the magnetic field at the stator will induce voltage or current on the rotor and an opposite magnetic field will be created.

When the motor is fed by a symmetric three phase system (phases electrically 120° apart), they will create a rotating magnetic field, as per *Figure 6*.

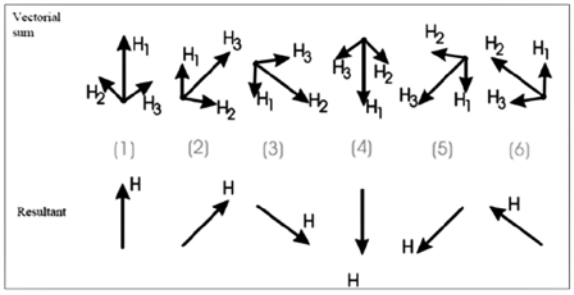

Figure 6: Rotating magnetic field on a three phase motor.

The interaction between the magnetic field on the stator and the induced magnetic field on the rotor will make the motor run.

When running on a VSD, the VSD will still provide the motor with a three phase signal on its output, but you could feed the input of the VSD with a single phase voltage, which means, the existing installation could be used without any modification simply by feeding the single phase voltage to a VSD instead of to a starter.

It is relevant to mention that this will be available for a 220 V single phase supply (input of the VSD), as long as the motor can be connected for a 220 V three phase supply (output of the VSD).

For example a 380/ 660 V three phase motor would not be suitable if the single phase voltage available on site is 220 V. Most of the motors on these small sizes would have 220 V available.

The VSD will then rectify the voltage and from a dc link provided by a capacitor bank, switch the voltage on and off with IGBTs to create the three phase signal on the output to feed the motor. Basic VSD construction can be seen in *Figure 7*.

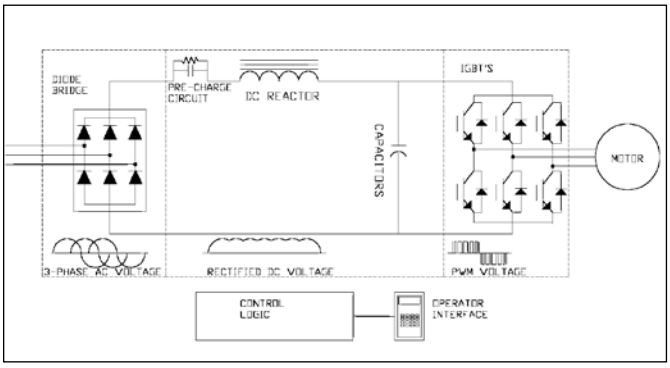

Figure 7: Basic VSD construction.

Technical comparison

In general three phase motors will present a better efficiency and power factor than a single phase motor and they are also more reliable and require less maintenance as no capacitor or internal switches are needed. Single phase motors are also heavier.

Single phase motors are only really used where no three phase voltage is available, but with the more easily accessible VSD, which can have a single phase supply, this is no longer a problem.

Table 1 shows a quick comparison between a single and a three phase motor.

Besides the performance and reliability of the motors, by using a three phase motor running on a VSD, it is also no longer necessary to have a DOL starter with contactors and thermal relays, as all the protections are now built into the VSD.

kW	Voltage	Frame	Single phase				Three phase			
		Size	Efficiency	Rated current (A)	Absorbed kVA	Weight	Efficiency	Rated current (A)	Absorbed kVA	Weight
0,55	220	80	68,0%	4,60	1,01	14,4 kg	68,2%	2,46	0,94	10,2 kg
0,75	220	80	68,0%	6.20	1,36	14,5 kg	72,1%	3,25	1,24	11,0 kg
1,1	220	90 L	74,0%	8,15	1,79	18.9 kg	75,5%	4,55	1,73	15,3 kg
1,5	220	90 L	72,0%	11,50	2,53	20,9 kg	77,5%	5,91	2,25	16,6 kg
3	220	112 M	78,2%	19,00	4,18	42,1 kg	81,5%	11,50	4,38	24,2 kg
5,5	220	132 M	82,5%	32,00	7,04	54,6 kg	85,0%	19,70	7,50	43,9 kg
7,5	220	132 M	83,0%	42,00	9,24	80,8 kg	86,0%	26,10	9,93	50,0 kg

Table 1: Performance comparison.

The VSD will also provide additional features not available on a normal starter for single phase motors, such as:

- Current reading
- Speed reading
- Under voltage protection
- Phase protection
- Fault history
- Speed variation allowing power saving

The VSD would have incorporated analogue inputs and outputs as standard and also allow communication to a PLC or SCADA system.

Table 2 is a summary of the technical features of both options.

Feature	1 phase with starter	3 phase with VSD
Maintenance	Capacitors and internal switches	Low maintenance
Rated current	High	Low
Starting torque	High	Limited by the VSD
Speed control	No	Yes
Overload protection	Yes	Yes
Under-voltage protection	No	Yes
Weight	High	Low
Phase protection	No	Yes

Table 2: Technical comparison.

Commercial comparison

When doing a commercial comparison, we must not only compare the price of a single phase motor versus the price of a three phase motor, but take into account the starters.

Considering a single phase motor with a DOL starter and a three phase motor with a VSD, average prices are indicated in *Table 3*.

This comparison underpins the conclusion that in most of the cases, based on current market prices, it is cheaper to use a three phase motor with a VSD than a single phase motor with a starter. You also need to take into account the higher availability of three phase motors off the shelf as well as VSDs and the additional technical features that come with this combination (refer to the technical comparison in *Table 2*).

Motor kW	Three phase motor with VSD	Single phase motor with DOL starter	Single phase premium %
0,25	R1 830	R1 920	4,9%
0,37	R1 857	R2 092	12,7%
0,55	R1 962	R2 190	11,6%
0,75	R2 108	R2 425	15,0%
1,1	R2 350	R2 543	8,2%
1,5	R2 848	R3 165	11,1%
2,2	R3 625	R3 989	10,0%

Table 3: Commercial comparison.

Conclusion

From the technical and commercial comparisons made, you can clearly see the advantages of using three phase motors with a VSD.

It is correct to mention that the VSD has electronics on board which demand some additional care and sometimes people would just find it easier to have a normal starter, but the VSDs have become more user friendly requiring little maintenance and if you take into account all the additional features you get, it is definitely the way to go.

Commercially you would also see that with the reduction of the cost of VSDs over the years, it is safe to say that the combination of a three phase motor with a VSD is cheaper than a standard single phase motor with a starter.

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