# VFD and It's Compatibility with Aqua's Submerged Pumpsets

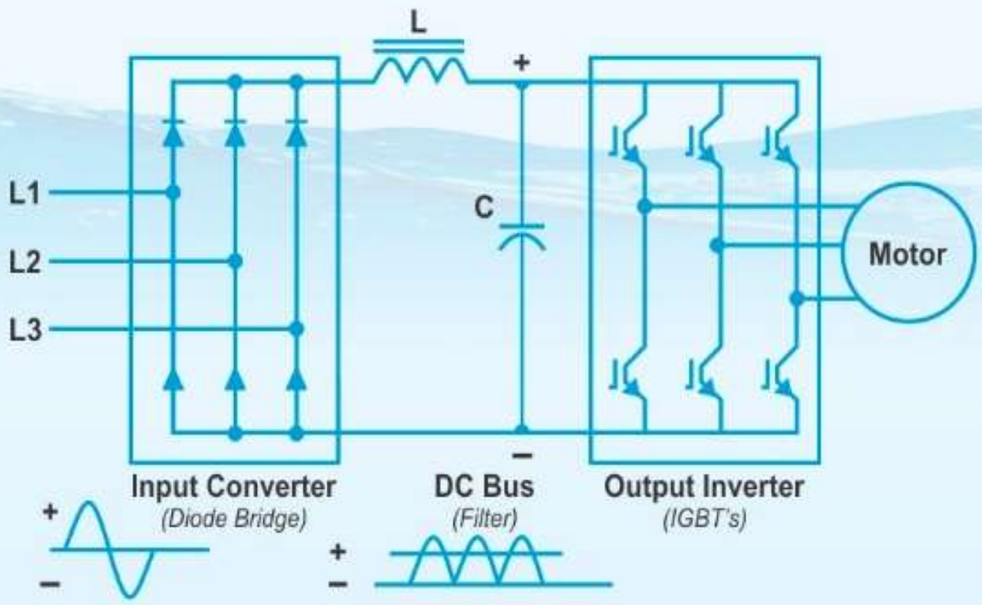
## Enhancing Efficiency & Performance

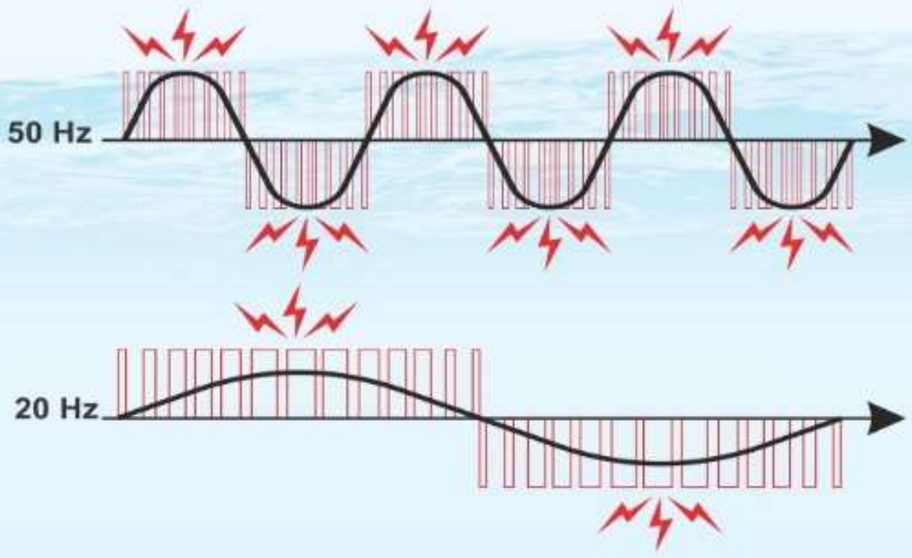

**can be Safely Operated** *(via VFD)* **at any** *(lower)* **Frequency / Speed**

**VFD**
Compatible

# What is VFD / VSD..?

*A Variable Frequency Drive (VFD/VSD) is a motor controller that varies the frequency & voltage of its power supply, providing precise control over motor speed and torque.*

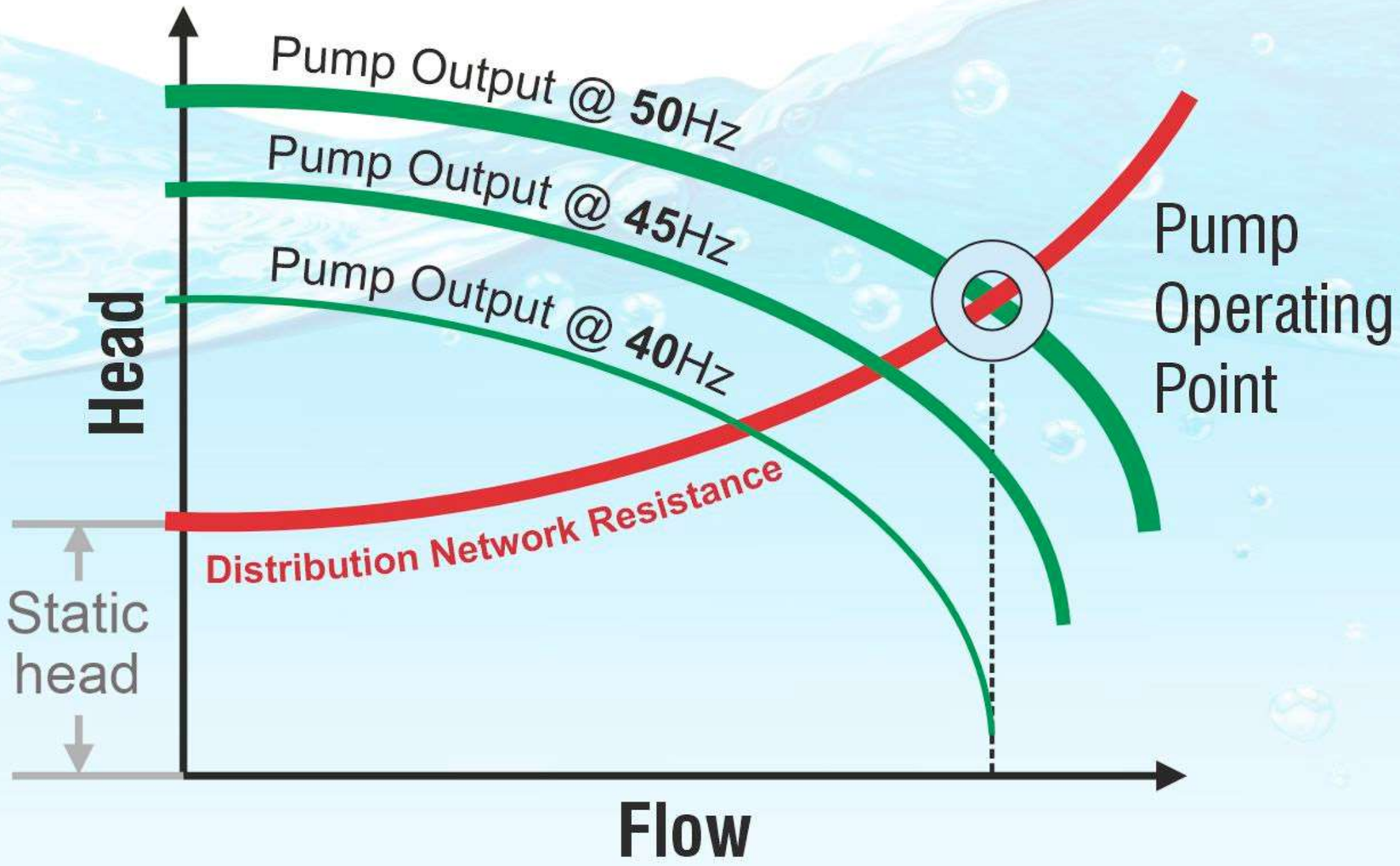
# Compatibility of VFD with Submerged Pumpsets:-

## How VFD's improve the Performance of Submerged Pumps.

1. *Power Saving.*
2. *Complete Control Over Motor Speed can be Achieve.*
3. *Smooth starting / Acceleration.*
4. *Control Flow without using Separate Controller (Valve).*
5. *Improved Power Factor.*
6. *No need additional pump motor Starter.*

In **24 x 7** systems; water is supplied Round the Clock which requires a vast Variation in the Head as well as the Flow out output of the pumpset. Often this is achieved using VFD to drive the pumpsets.

**Fully VFD Compatible**



# Typical benefit of VFD on Pump-Motor set

| Frequency | | Hz | 50 | 45 | 40 | 35 | 30 |
|---|---|---|---|---|---|---|---|
| | | % | *100%* | *90%* | *80%* | *70%* | *60%* |
| Pump | Sync Speed | rpm | 1500 | 1350 | 1200 | 1050 | 900 |
| | Head | m | **35.0** | **28.4** | **22.4** | **17.2** | **12.6** |
| | Flow | $m^3/hr$ | **1000** | **900** | **800** | **700** | **600** |
| | bkW | kW | 112.1 | 86.9 | 61.0 | 50.3 | 34.3 |
| Motor | kVAi | kVA | 147 | 118 | 87 | 74 | 54 |
| | V | V | **415** | **374** | **332** | **291** | **249** |
| | | % | *100%* | *90%* | *80%* | *70%* | *60%* |
| | A | Amp | **204** | **182** | **152** | **147** | **124** |

However, satisfactory operation of any Motor depends upon its *(Stator Insulation)* Temperature which in turn relies upon the rate of Heat Dissipation always being more than that of Heat Generation

should be examined on a case-by-case basis. Usually, it is advantageous to select the pump such that the system curve intersects the full speed pump curve to the right of best efficiency, in order that the efficiency will first increase as the speed is reduced and then decrease. This can extend the useful range of variable speed operation in a system with a static head. The pump manufacturer should be consulted on the safe operating range of the pump. Further details may be referred at section 5.16.1 of this chapter.

The introduction of VFDs requires additional design and application considerations - additional information can be obtained from pages 12, 13, and 14 of "Variable Speed Pumping - A Guide to Successful Applications" published by Hydraulic Institute Standards, Euro Pump and U.S. Department of Energy.

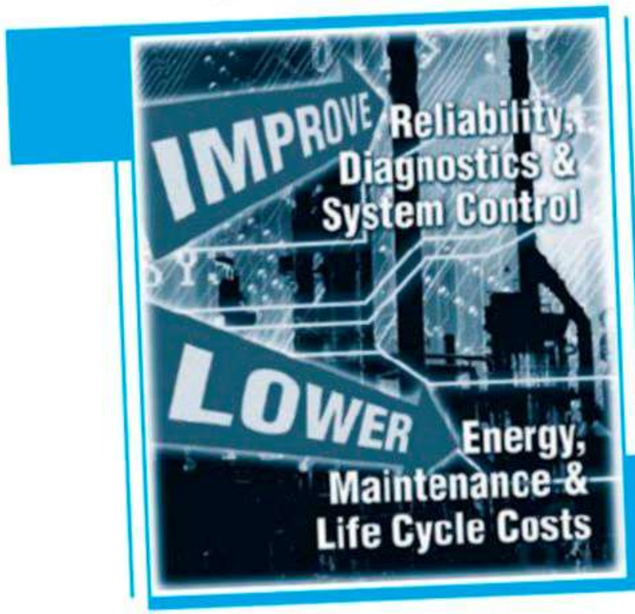
Motor for VFD system should be VFD Compliant certified by the motor manufacturer.

*Source:* ***Govt of India, MoHUA, Manual on Water Supply 2023***

# VARIABLE SPEED PUMPING

## A GUIDE TO SUCCESSFUL APPLICATIONS

EXECUTIVE SUMMARY




## VARIABLE SPEED DRIVES A WAY TO LOWER LIFE CYCLE COSTS

Hydraulic Institute

Europump

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Industrial Technologies Program

## Potential Drawbacks of VSDs

VSDs also have some potential drawbacks, which can be avoided with appropriate design and application.

***Structural Resonance***

Resonance conditions can cause excessive vibration levels, which in turn are potentially harmful to equipment and environment. Pumps, their support structure, and



piping are subject to a variety of potential structural vibration problems (resonance conditions). Fixed-speed applications often miss these potential resonance situations because the common excitation harmonics due to running speed, vane passing frequency, plunger frequency, etc., do not coincide with the structural natural frequencies. For VSD applications, the excitation frequencies become variable and the likelihood of encountering a resonance condition within the continuous operating speed range is greatly increased. Pump vibration problems typically occur with bearing housings and the support structure (baseplate for horizontal applications, motor and stool for vertical applications).

**A number of analyses may be performed to predict and avoid potential resonance situations.**

*Source:* ***HIS, EuroPump & US DoE***

## Rotor Dynamics

The risk of the rotating element encountering a lateral critical speed increases with the application of a VSD. Lateral critical speeds occur when running speed excitation coincides with one of the rotor's lateral natural frequencies. The resulting rotor vibration may be acceptable or excessive, depending on the modal damping associated with the corresponding mode. Additionally, drive-induced torque harmonics may cause resonance conditions with torsional rotor dynamic modes. However, such conditions are usually correctible or preventable.

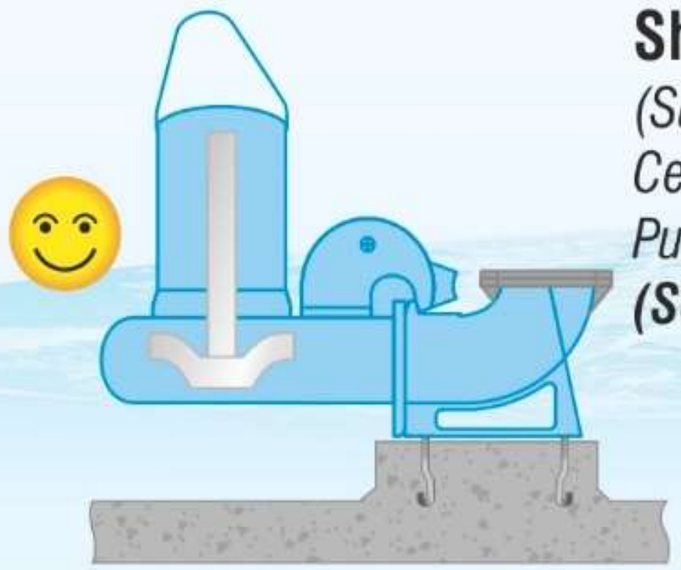
Variable speed vertical pumps are more likely than horizontal machines to exhibit operational zones of excessive vibration. This is because such pumps' lower natural frequencies are more likely to coincide with running speed. Small, vertical close-coupled and multistage pumps normally do not present this type of problem.

*Source:* ***HIS, EuroPump & US DoE***

# *A Strong, Mono Shaft for Fail Safe Operation*

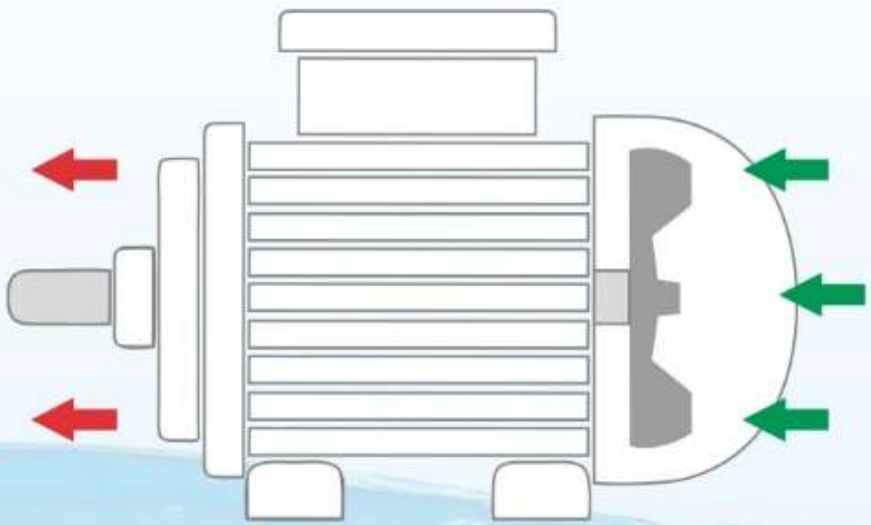
**Multiple, Jointed; Long Slender Shafts** *(Vertical Turbine Pumpset* ***(VT))***

**Single, Rigid; Robust Shaft** *(Submerged Centrifugal Pumpset* ***(SCF))***



As the **Critical Speed** of Submerged Centrifugal Pumpsets lies *Safely Above* it's Maximum Speed, there is **No Risk of Resonance** or **Vibration** *(when speed is varied with VFD)*

# Risk Motor : Heat Dissipation v/s Speed



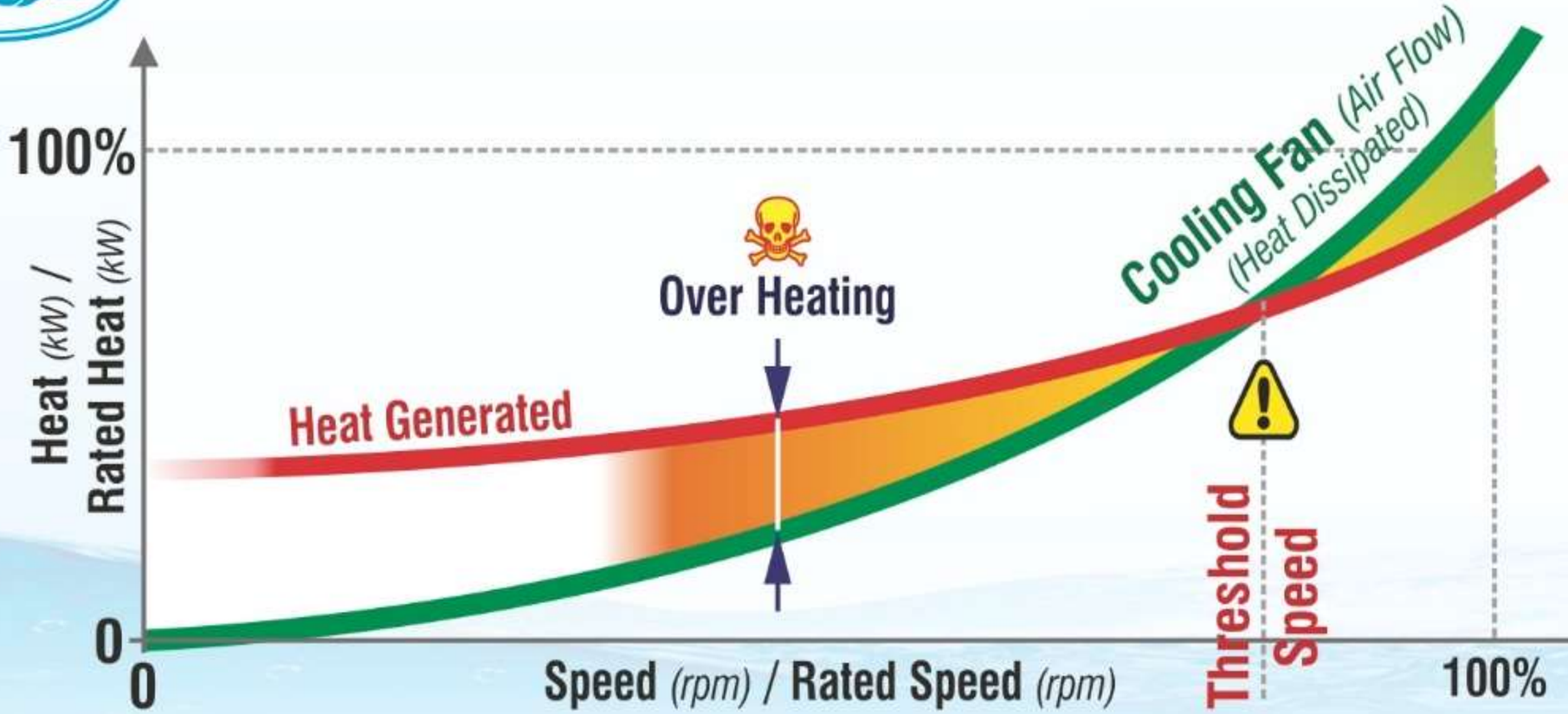
Totally Enclosed
**Air Fan** Cooled
*(TEFC)*
*(Squirrel Cage Induction)*
**motor**
*(Shaft Mounted Fan - IC4A1A1)*

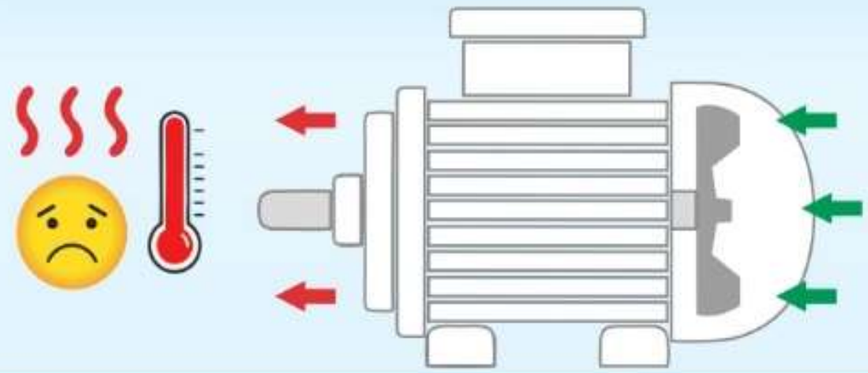
In case of typical Air Cooled *(TEFC)* motors, Heat Dissipation *(Cooling)* is by mode of Forced Air blown by a *(Centrifugal Axial)* Fan mounted on the motor shaft itself.

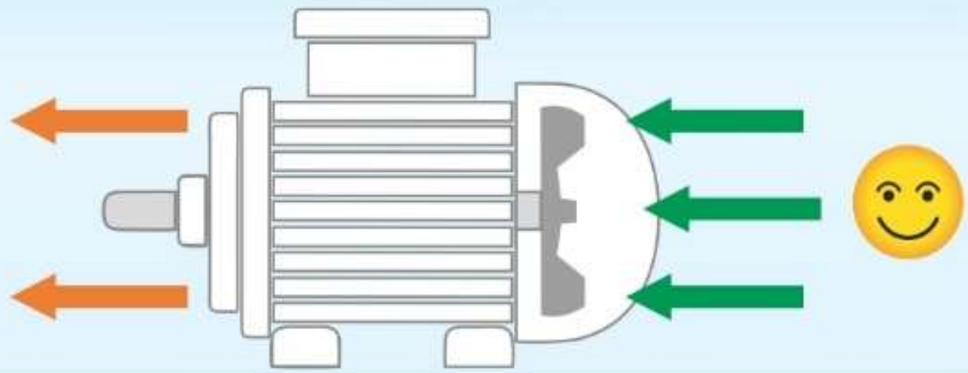
As per the basic law of centrifugal machines, the Fan's Output *(Heat Dissipation)* is proportional to the cube of it's speed.

Hence when such motor's speed is slowed down by VFDs, the Cooling Fan *(being mounted on the motor's shaft)* also slows down & subsequently the motor's Cooling Air Flow *(heat dissipation)* reduces drastically - so much so that below a threshold speed; the motor can Overheat to unacceptable levels.

# Conventional Motor : Heat Dissipation v/s Speed

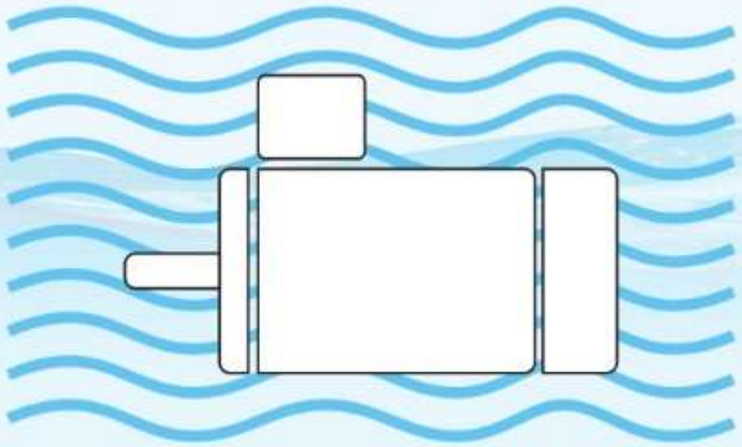




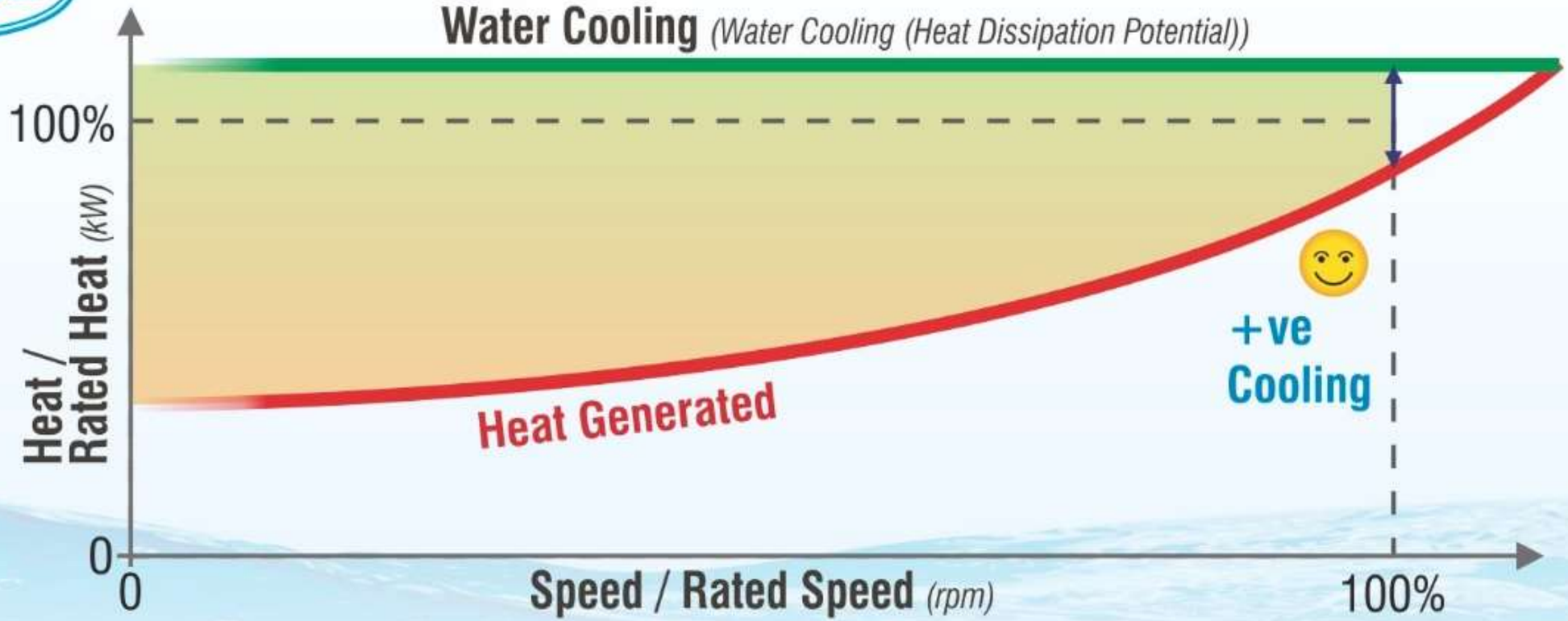
# Submerged Motor : Heat Dissipation v/s Speed

Totally Enclosed *(IP68)* Water Cooled *(TESWC) (Squirrel Cage Induction)*
Submerged motors are cooled *(quenched)* by Surrounding Water – hence it's cooling effectiveness is not dependent on the speed *(or VFD)*.



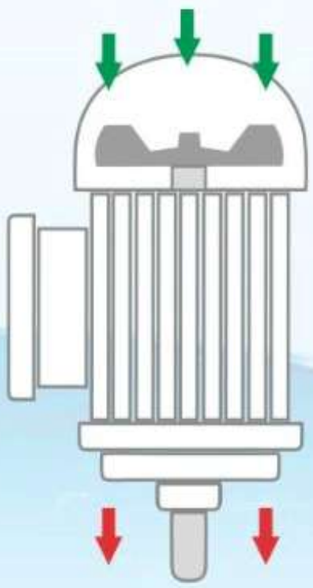
Totally Enclosed *(IP68)* **Water** Cooled ***(TESWC)*** *(Squirrel Cage Induction)*
**Submerged Motor** *(Self Surface Water Cooled - IC4A1W0)*

# Submerged Motor : Heat Dissipation v/s Speed




# Side Effects of VFD's: **Motor Cooling**

**Satisfactory operation of any Motor depends upon its** *(Stator Insulation)* **Temperature which in turn relies upon the rate of Heat Dissipation always being more then that of Heat Generation.**



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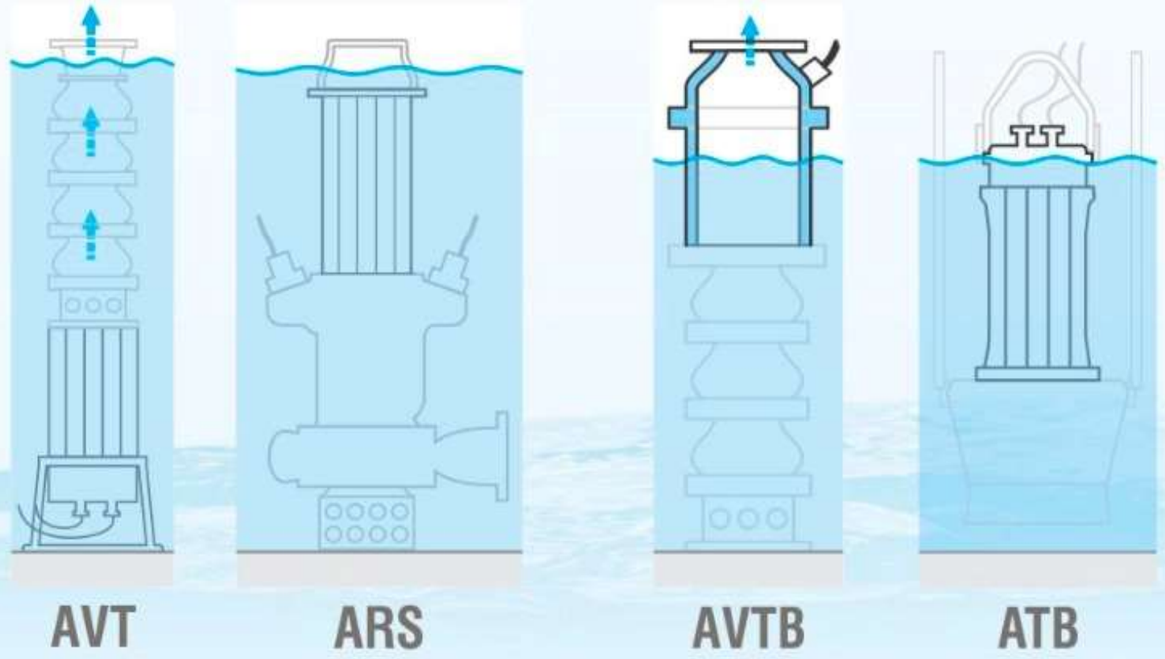
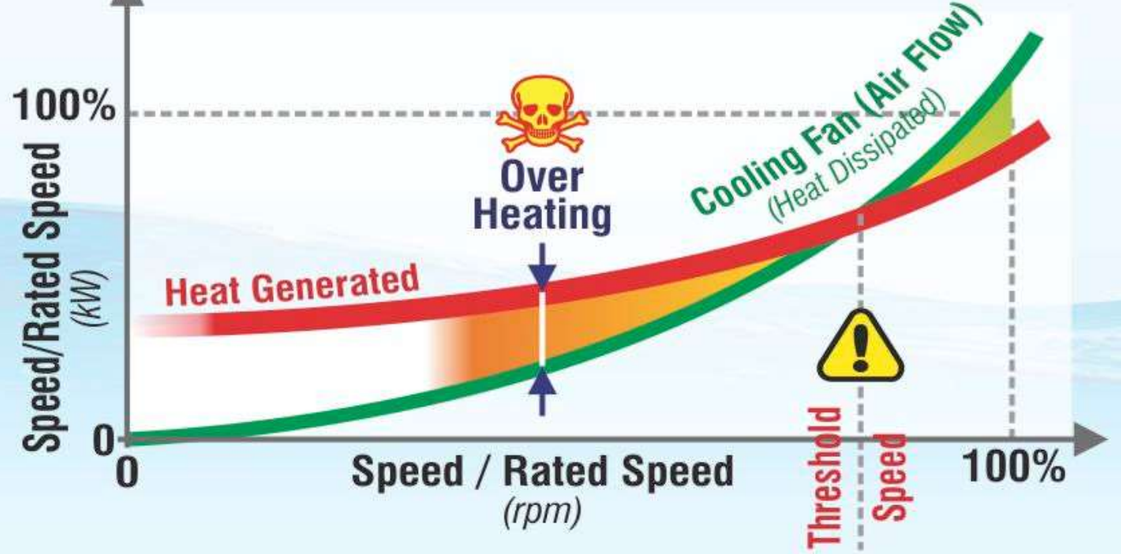
Totally Enclosed **Air Fan** Cooled ***(TEFC / CACA)***
*(Squirrel Cage Induction)*
**Motor** of **Conventional VT** Pump
*(Shaft Mounted Fan - IC4A1A1)*

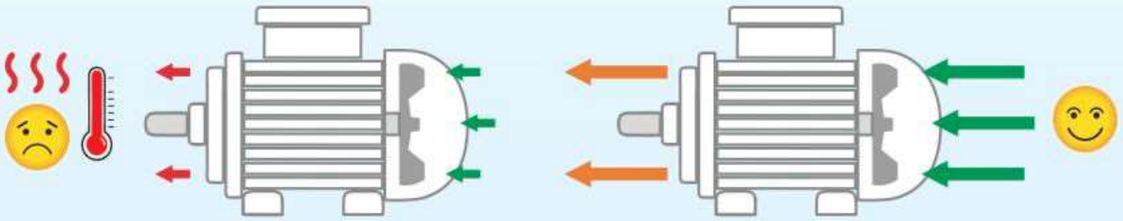



Totally Enclosed ***(IP68)*** **Water** Cooled ***(TEWC)***
*(Squirrel Cage Induction)*
**Submerged Motor**
*(Self / Pumped water cooled - IC4A1WO / IC4A1W1)*

# Side Effects of VFD's: **Motor Cooling**

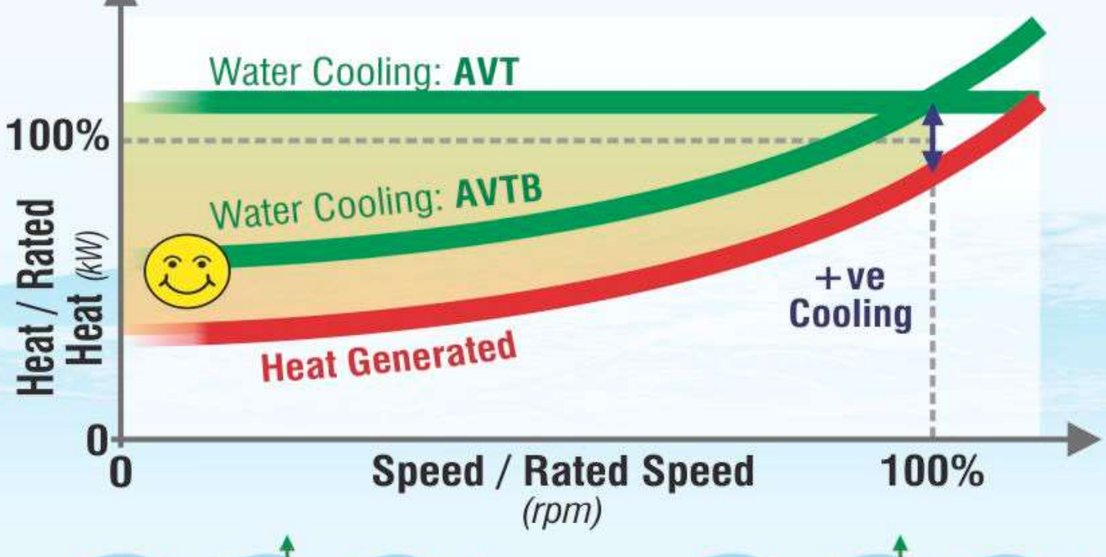
Hence when such motor's speed is slowed down by VFDs, the Cooling **Fan** *(being mounted on the motor's shaft)* **also Slows down** & subsequently the motor's **Cooling Air Flow** *(heat dissipation)* **Reduces Drastically** - so much so that below a threshold speed; the motor can **Overheat to unacceptable levels.**



**Submerged** motors are **always effectively** cooled by **Water** *(whose Cooling **Effectiveness is insensitive to the Speed.)***

**VFD Compatible**




# Typical effects of VFD on Various Types of Pump-Motorsets

*(rated parameters 125kW, 1500rpm (sync) 4P; 35m x 1000m3/hr @ 50Hz)*

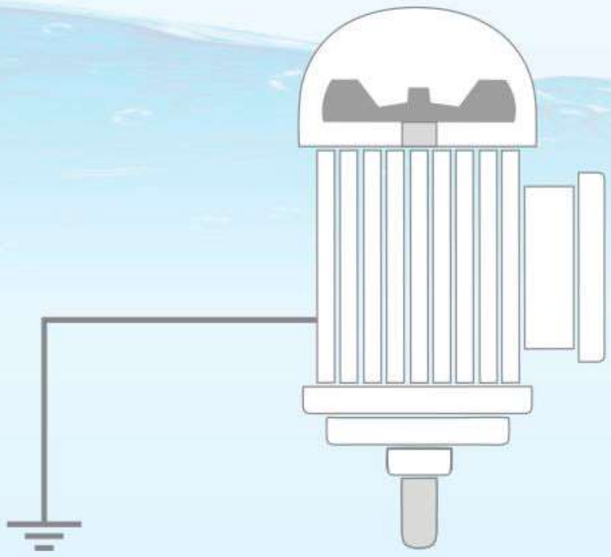
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Frequency** | | Hz | **50** | **45** | **40** | **35** | **30** |
| | | % | *100%* | *90%* | *80%* | *70%* | *60%* |
| **Pump** | **Speed** *(sync)* | rpm | 1500 | 1350 | 1200 | 1050 | 900 |
| | **Head** | m | **35.0** | **28.4** | **22.4** | **17.2** | **12.6** |
| | **Flow** | $m^3/hr$ | **1000** | **900** | **800** | **700** | **600** |
| | bkW | kW | 112.1 | 86.9 | 61.0 | 50.3 | 34.3 |
| **Motor** | kVAi | kVA | 147 | 118 | 87 | 74 | 54 |
| | **V** | V | **415** | **374** | **332** | **291** | **249** |
| | | % | *100%* | *90%* | *80%* | *70%* | *60%* |
| | A | Amp | **204** | **182** | **152** | **147** | **124** |
| | Heat Generated **Iron** Losses | kW | 1.63 | 1.20 | 1.05 | 0.86 | 0.74 |
| | Heat Generated **Copper** Losses | kW | 7.80 | 6.20 | 4.85 | 3.55 | 2.36 |
| | Heat Generated **Stray** Losses | kW | 1.96 | 1.20 | 0.80 | 0.55 | 0.38 |
| | **Total Heat Generated** | kWh | **11.39** | **8.60** | **6.70** | **4.98** | **3.48** |
| **TEFC Air Cooled motor** | **Cooling Fan Flow** *(Heat Dissipated)* | cfm *(kWh)* | **11.75** | **8.57** | **6.70** | **4.97** | **3.48** |
| | **Heat Dissipated / Heat Generated** | % | **103%** | **100%** | **90%** | **81%** | **73%** |
| | | Condition | **Cool** | **Cool** | ⚠ **Heats up** | ☠ **Heats up** | ☠ **Heats up** |
| **Submerged Water Cooled Motor** | **Water Cooling** *(Heat Dissipation Potential)* | kWh | **11.75** | **11.75** | **11.75** | **11.75** | **11.75** |
| | **Heat Dissipated / Heat Generated** | % | **103%** | **137%** | **175%** | **236%** | **337%** |
| | | Condition | **Cool** | **Cool** | **Cool** | **Cool** | **Cool** |

*Thanks to Unchanged cooling effect of Surrounding Water: Submerged motors can be blindly used with VFDs while still being always effectively cooled at any Speed.*

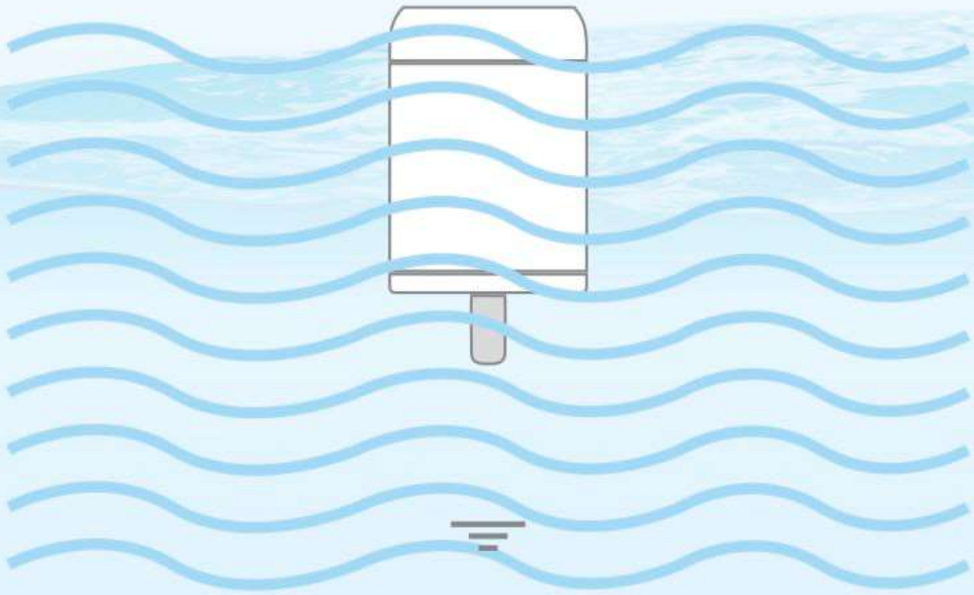
# Side Effects of VFD's: **Capacitive Charge**

VFDs induce **Capacitive Charge** *(Static Electricity)* **Build Up** in motors.

**Surface Mounted**, TEFC / TETV / CACA motors *(of Conventional VT pumps)* require **Fail Safe Grounding** *(to safely dissipate this static built up charge)* to avoid Shock to Operator. ⚠

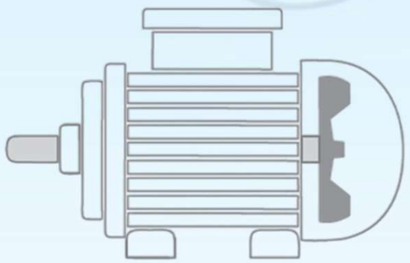


Submerged motors *(of AVT / AVTB)* being immersed under / in contact with water; **Automatically & Safely Always Dissipate** their **Static Electricity into Water** *(no risk to operator even if Earthing System is weak or not connected by mistake).*

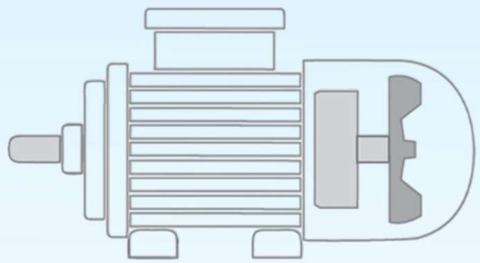


# VFD & Motor:- Cooling Effectiveness

To overcome this problem *(of overheating during reduced speeds);* clients sometimes use *(costly)* **External Motorized Fan** *(IC 416A)* motors which use a Separate Motorized Fan whose output does not change with (main) motor speed reduction - this however increases **Complexity & Maintenance** *(as now there are 2 motors instead of 1 to operate & maintain).*

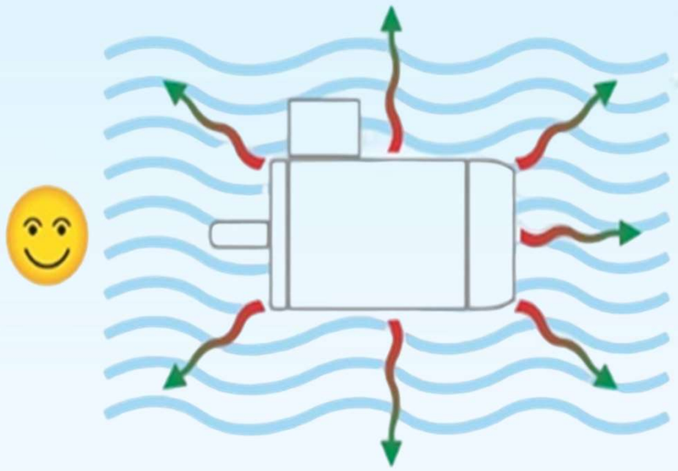


**TEFC Air Cooled Motor**
**(Shaft Mounted Fan - IC411)**



**Air Cooled Motor**
**(with External Motorized Fan - IC416A)**

A simpler & better solution *(where ever water is available)* is to use Totally Enclosed, Self *(Surface)* Water Cooled Submerged Motors which are cooled **uniformly** by **water irrespective of the speed**.



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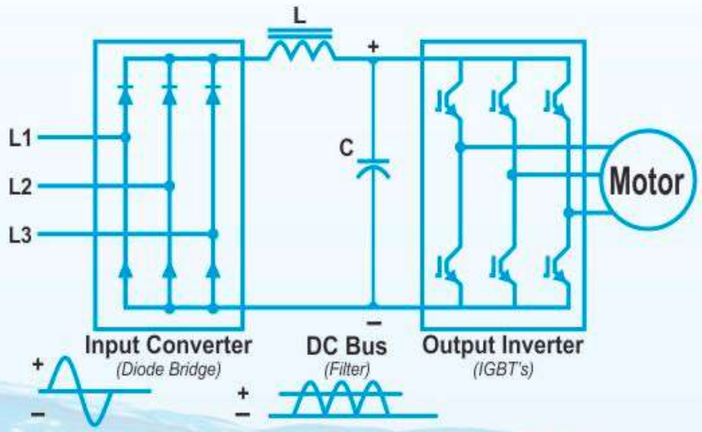
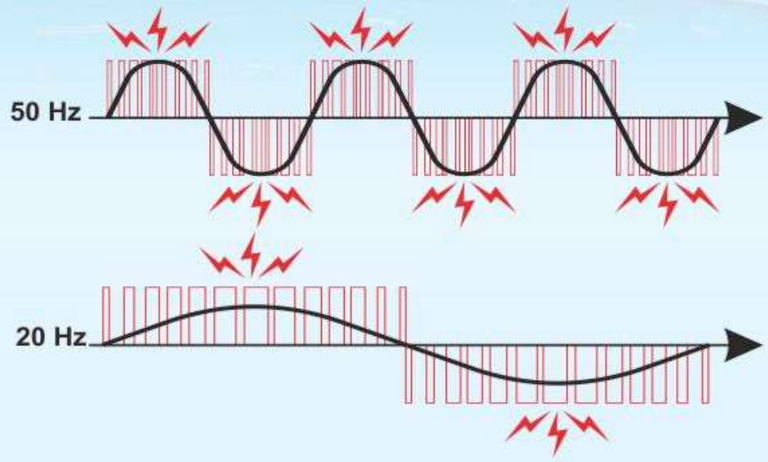
**VFD Compatible**

# VFDs & their Impact on Motors: Stress on Motor Insulation Side Effects of Speed Control of Pumpsets via VFD's:

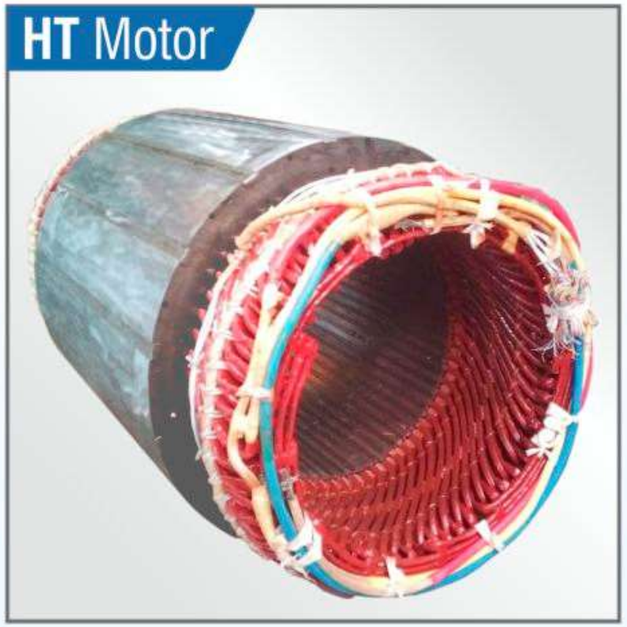

Generate PWM *(Pulse width modulation)* Output with High Harmonic Distortion which causes severe Di-Electric stress *(on Motor's Stator's Winding Insulation)*,




Harmonic Distortion due to VFD causes severe stress on Di-Electric on Motor's Stator's Winding Insulation Leading to its accelerated aging & even failures...!

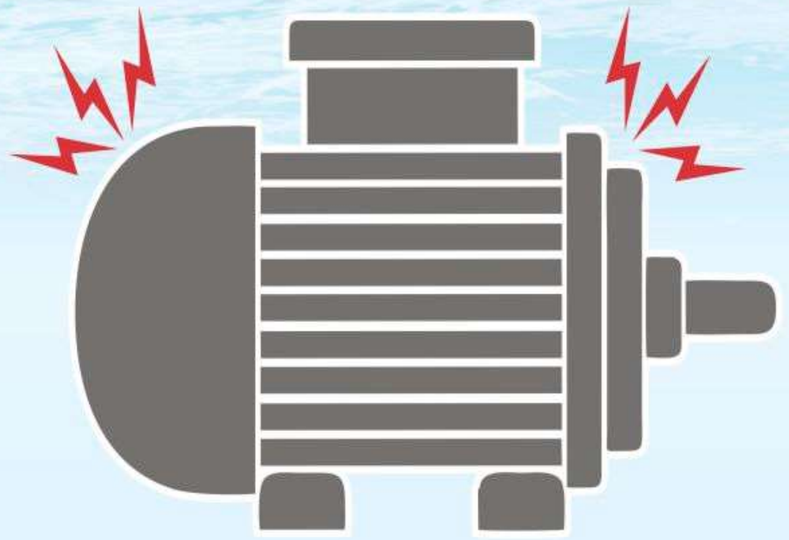
# High DiElectric Strength Winding Insulation

**Fully VFD** Compatible

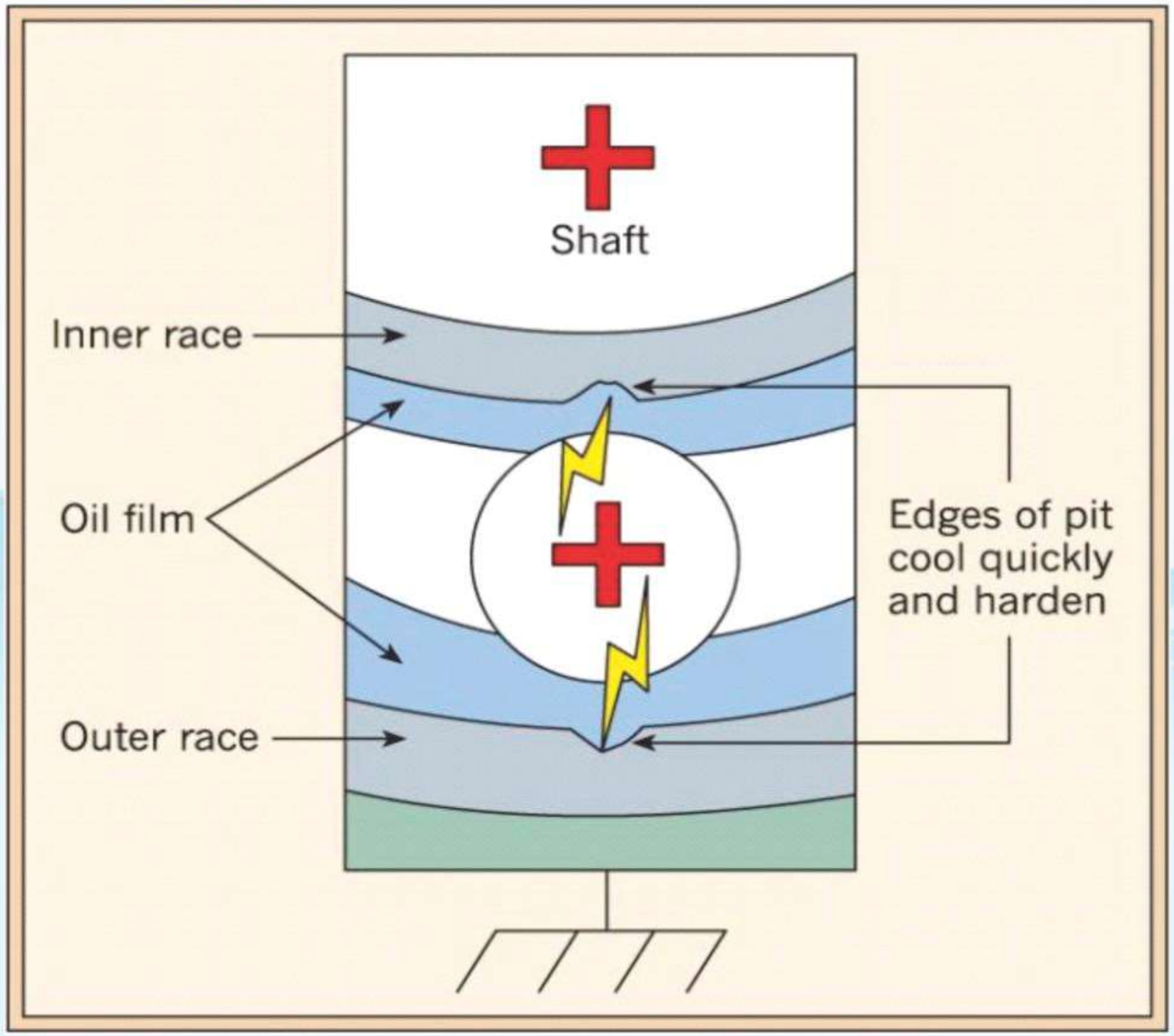




Thanks to Additional **Mica** *(Over & Above Glass Fibre Aramid)*, **+ Vacum Pressure Resin Impregnation** *(VPI)*; Aqua's Motor's **LT/HT Insulation** has **extremely High** Motor Stator Winding **Di-Electric Strength** enabling it to work satisfactorily even when fed by **VFD.**



# VFDs Induce Shaft Bearing Circulating Currents in Larger Motors




# VFDs Induce Shaft Bearing Circulating Currents in Larger Motors

Larger motors are always offered with **Current Insulated NDE Bearing Housings**, reducing the risk of bearing failures arising from internal Rotor-Stator-Bearing Circulating Currents excited by **VFD's.**

# VFDs & their Impact on Motor : Noise Level

Conventional Pumps use **Air** Cooled ***(TEFC / CACA)*** **motor** which **dissipate** their **Heat** & **Noise** into the Operating Room.

Sub CF

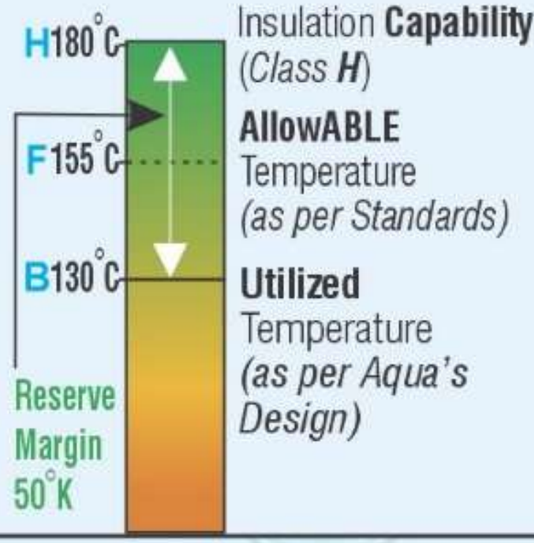
**Submerged** motors are cooled by **Water** & hence the **Operating Conditions** are **Cool** & **Noiseless.**

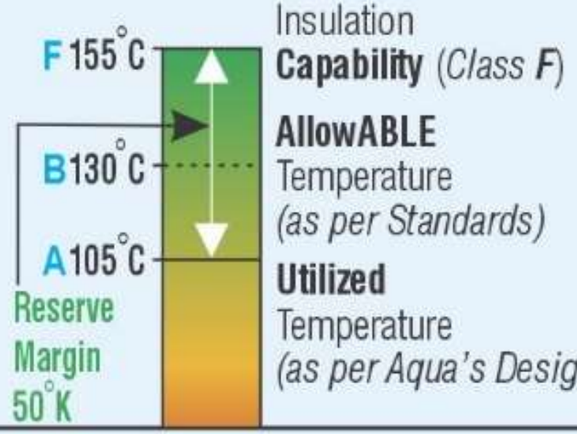
**Lower NVH** *(Noise, Vibration & Harshness)* **Levels**

Due to the harmonics, the motor noise level will increase when it is operated using a VFD.
This "extra" noise level depends mainly on the inverter switching frequency and harmonic content.
Aqua's Submerged Pumpsets produce minimum noise because motor submerged in water.

# Frequently Asked Questions

## Aqua



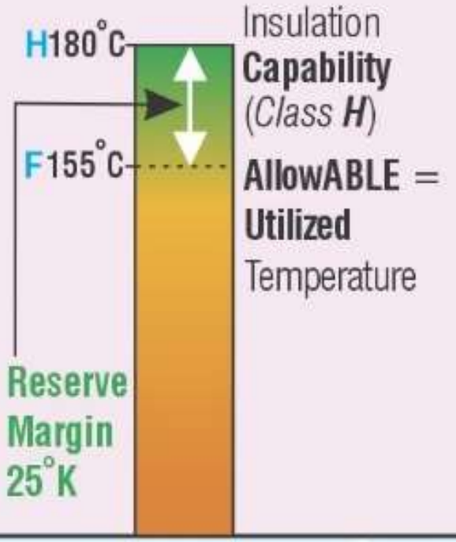




Hence, Aqua's Motors have a **50°K** Thermal Reserve **Margin** *(v/s just 25°K of Competitors)* leading to **Better** Life

**Option1** :
(*Medium & Large LT Motors*)
**Class "H" Insulation x Class "B" Utilization**

**Option2** :
(*HT & some LT Motors*)
**Class "F" Insulation x Class "A" Utilization**

## Competitors


Competitor's Motors have **just 25°K** Thermal Reserve **Margin**

Class "**F**" Insulation x Class "**B**" Utilization Fully use up motor's reserve margin (*as allowed by tender*)

Class "**H**" Insulation x Class "**F**" Utilization Fully use up motor's reserve margin (*as allowed by tender*)

# Design : **Motor END**

Ultra High **Di-Electric** strength *(of Motor's Insulation)* due to costlier **Resin** impregnation *(v/s cheaper **Varnish**)* helps safe operation even in poor Power Supply

**V**acuum **P**ressure **I**mpregnation Treatment (**VPI**) *(also known as **Power House** Treatment)* is provided by Default at **no extra cost**

Specially Designed for **Ease** of **Local Repairs** Thanks to the use of Easily Available, *(Non Proprietary)* & Standardized Components *(like Mechanical Seals, Grease, etc)*; Repairs of Aqua's pumpsets is Easier & Economical

Designed for upto **55°C Ambient temperature**

# Thank You !

Aqua Machineries Pvt. Ltd.

www.aquapumps.com