Wye - Delta Starting of Centrifugal Fire Pumps -- Truths and Myths

Background: The purpose of this paper is to provide application data and general information on the use of Wye-Delta (Star-Delta) starting of centrifugal fire pumps. This information is meant to dispel or correct some of the myths and misunderstandings about this method of motor starting.

We regularly receive reports that some fire pump controller manufacturers are factory setting accelerate timers on Wye-Delta fire pump controllers to only one or two seconds; and, also warning increasing this time will void the warrantee on the controller. Further, we also have received reports that some of these manufacturers stating that this necessary on all such controllers by all manufacturers, including ourselves. This is not true and is the main reason for this paper.

General: There are nine commercially available methods of starting centrifugal fire pumps from manufacturers of U.L. Listed and F.M. Approved Fire Pump controllers. These are listed in the chart below. Also listed is the factory settings of the six reduced inrush starting methods offered by M.C.S. These settings apply equally to both our EC* Series and MC* Series controllers. All of the above methods of reduced inrush starting are closed transition except for 4).

Common Centrifugal Fire Pump Motor Starting Methods and M.C.S. Factory Standard Accelerate Times
(Parenthetical Names are Alternate Designation)

1) Single Step Full Voltage (Across-the-Line, Direct-on-Line) = Not Applicable (zero)
2) Two Step Part Winding (Half Winding) = 3 seconds
3) Primary Reactor (Series Reactor) = 3 seconds
4) Open Transition Wye-Delta (Star-Delta) = 7 seconds
5) Closed Transition Wye-Delta (Star-Delta) = 7 seconds
6) Soft Start (SCR) = 10 seconds (fixed, non-adjustable).
7) Auto transformer (Transformer) = 3 seconds.
8) Variable Speed Starting = one of the above in Bypass Mode only.
9) Primary Resistor (Series Resistor) = Not offered by M.C.S. See 3) above instead

Myth #1: Accelerate times for Wye-Delta Open Transition controllers must be limited to one or two or three seconds (varies with the particular myth in question.
Fact #1a: NFPA-20 limits accelerate times to 10 seconds maximum.
Fact #1b: The Accelerate Time of any M.C.S. reduced inrush controllers can be and may be set to the full 10 seconds allowed by the standard.

Myth #2: Accelerate times for Wye-Delta Closed Transition controllers must be limited to one or two or three seconds (varies with the particular myth in question.
Fact #2: Same as with Myth #1.

Myth #3: A Wye-Delta controller can accelerate the fire pump motor to full speed in one to three seconds.
Fact #3a: No fully loaded fire pump motor will come up to speed with Wye-Delta (Open or Closed Transition) starting in one, two, ten or any number of seconds regardless of whether the fire pump is loaded or at churn (shutoff), unless the motor is considerably oversized. This is because the motor torque in the Wye starting mode is only 33% of full voltage starting torque. Although a centrifugal fire pump represents a low inertia load, this is not nearly enough torque to get the motor anywhere near full speed in this time. See, for example compare the torque curves for full voltage (ATL - DOL) starting with that for Wye-Delta starting:

http://mastercontrols.com/ProdInfo/Catalogs/ECat04.htm (ATL - DOL)

http://mastercontrols.com/ProdInfo/Catalogs/ECat07.htm (Wye Delta Open) -or-
http://mastercontrols.com/ProdInfo/Catalogs/ECat08.htm (Wye Delta Open)

Note that these Wye-Delta curves are for 1800 RPM pumps. The torque deficit is even worse for modern 3600 RPM pumping units.

Fact #3b: Wye-Delta starting is commonly used for unloaded motor starting, such as with centrifugal chillers, for example. Where starting time can be long enough for accelerating the motor, this method is feasible and is widely used in the HVAC and other industries. However, a centrifugal pump, such as a fire pump, represents a substantial load to the motor even at churn (shutoff).

Myth #4: A Wye-Delta controller can accelerate the fire pump motor to full speed in ten seconds.
Fact #4: The 33% accelerating torque provided by Wye-Delta starting will not accelerate a fully loaded pump, and in many cases even an unloaded pump, in ten seconds or a hundred seconds or ever. There is simply not enough torque, at 33% of A-T-L torque, to get the motor anywhere near full speed in this time. The reason for this is that the motor torque curve will cross the pump torque curve for any fully load pump, and most other cases as well. As such, the motor will only get the pump to a limited speed. Some modern pumps draw very close to full load amps at churn (pump shutoff). These pumps will not be up to speed in one, ten, or a thousand seconds. Expect close to locked rotor after the accelerate timer times out.

Myth #5: Wye-Delta is OK for fire pumps since it's widely used in Europe and also for HVAC applications in the U.S.
Fact #5: Wye-Delta starting is commonly used for starting unloaded, or lightly loaded motors. Also, the power supply (mains) usually limit the magnitude of transition spike currents. However, a centrifugal pump, even at churn represents a substantial load to the motor. This, plus with a stiff power source, Open Transition Wye-Delta can have a substantial spike current hazard due to out of phase closing.

Myth #6: Wye-Delta controllers reduce the starting currents to only 33% of locked rotor current.
Fact #6: Not for long. In actuality, this only true during the accelerate period. After that, the motor will draw near Locked Rotor (LRA) current when the transition to the Delta (full voltage) running mode occurs. This second starting current magnitude is reduced only slightly by the vary small amount of motor speed gained in the one or two second accelerate time provided by competing units.

Myth #7: There is no danger of tripping the circuit breaker with Open Transition Wye Delta Starting.
Fact #7: Wye-Delta Open Transition controllers can and do create a current spike (transient) upon transition from the Wye starting mode to the full voltage Delta running mode unless means are used to control the phase angle between the motor back EMF and that of the line (mains) voltage. This transient is a function of the speed that the motor attains in the Wye Starting Mode, and the amount of phase angle difference at the moment of transition to the full line voltage (Delta) configurations. The resulting spike can be up to 18 times FLA. See (white paper / slide show) for more:

http://mastercontrols.com/EngInfo/Articles/Nailen/TA_RNail.htm
http://mastercontrols.com/EngInfo/Articles/Barr/TA_RBarr.htm
http://mastercontrols.com/EngInfo/Articles/Wooddall/TA_RWood.htm

which are from this page: http://mastercontrols.com/EngInfo/MCEngInf.htm#TechArts

Myth #8: All Open Transition Wye-Delta controllers must have the accelerate timer set to no more than one or two seconds.
Fact #8: Only if the transition to full voltage is uncontrolled. If a Wye-Delta Open Transition motor does come close to speed during the accelerate period, the potential transition transient (current spike) is substantial since the spike magnitude is a function of the speed attained. This is the real reason for cutting

the accelerate time so short.

Myth #9: Ditto (same myth again).
Fact #9: M.C.S. Open Transition controllers with that are equipped with our Leading Phase Monitor (LPM unit) avoid the transition transient problem altogether.

Myth #10: Ditto (same myth yet again).
Fact #10: No properly designed and built Closed Transition Wye-Delta starter should ever have a transition spike problem. That's the purpose for the transition resistors in the first place.

Myth #11: Ditto (same myth still again).
Fact #11: When the transition resistors are properly sized, there is no danger of resistor failure or burnout. When properly sized (both in ohms and ampere ratings), the resistors remain within their rated temperature limits even after numerous starts.

Myth #12: All Closed and Open Transition Wye-Delta controllers need the accelerate timer set to no more than one or two seconds
Fact #12: There is no reason for this limitation if the equipment is properly designed and built. That's why any of our reduced inrush controllers can be and may be set to the maximum allowed 10 seconds.

Myth #13: Primary Reactor Starting is inferior to the other six reduced inrush starting methods.
Fact #13: The fastest acceleration starting method is Primary Reactor. This is far faster and far more efficient than the Primary Resistor method offered by our competitors. Full speed acceleration normally occurs in less than three seconds, which is the factory default accelerate timer setting. For a detailed explanation of how and why, see either of these slide shows:

05) http://mastercontrols.com/EngInfo/Articles/Nasby/Slide_Shows/IFPA_Motors_20050111b.pps
06) http://mastercontrols.com/EngInfo/Articles/Nasby/Slide_Shows/IEEE-IAS_Motors_20040221.pps

Handouts for these two shows can be found here: http://mastercontrols.com/AboutFPC/MCSldA00.htm

Myth #14: Primary Resistor Starting is a valuable fire pump starting method.
Fact #14: Some people call Primary Resistor starting "Primary Toaster Oven" starting due the propensity of this method to cause smoke when the resistors become incandescent. This method draws more KW in the starting mode, by far, than any other reduced inrush starting method. The load on a generator set is worse than across the line starting at 314% versus 240%.

Myth #15: One or two second accelerate time setting is OK for Wye-Delta starting.
Fact #15: A Wye-Delta controller set to only one or two seconds becomes what some call a "Delayed Across-the-Line" starter, albeit an expensive (over priced) one. With these controllers, the motor will always, repeat: always, be subjected to locked rotor current. This is because so little speed can be built up on only one or two seconds with only 33% torque, which is all that Wye-Delta starting can deliver.

Myth #16: "…the transient is so short that it doesn't matter…"
Fact #16: Of course the transient matters. The circuit breakers (and isolating switches) used in modern controllers can and do trip in 1/2 line cycle (8 milliseconds), or less. This is how controllers can be rated at 100,000 amp short circuit current which is typical. This is also the approximate lenght of the transition transient. The proof is that fire pump breakers do trip if the Wye to Delta transient isn't well controlled.

Net results:
1) Any M.C.S. controller can be set for the full allowed ten seconds accelerate time, although Soft Start controllers are fixed at ten seconds.

2) No Wye Delta fire pump controller, neither Open Transition nor Closed Transition, will accelerate a fully loaded centrifugal fire pump in ten seconds, or ever, unless both the motor and controller are oversized by at least 27%.

3) There is no excuse for burned out starting or transition resistors under normal field conditions.

4) Wye Delta starting will always result in inrush (accelerating) currents at, or near, Locked Rotor after the accelerate period if the pump is fully loaded, and often when it's not.

5) Uncontrolled Open Transition Wye-Delta Controllers can, and do, cause sharp current spikes upon transition to the Delta running condition, especially if the pump does manage to come up to speed, due to out of phase conditions between the line voltage and the motor back EMF (residual motor voltage). Master Control's Leading Phase Monitor (LPM) equipped units avoids this problem.

6) wye Delta starting is both ineffective and overpriced when set to only one or two seconds of accelerate time. No pump will be anywhere near full speed in this short time. As a result, the bulk of the motor acceleration will occur after the transition to the full voltage (Delta) running mode. Hence the term, "Delayed Across-the-Line Starting".

7) All starting types, except Wye Delta, will fully accelerate a fire pump within the allowed ten seconds or less.

8) Primary reactor is the fastest accelerating method (highest overall starting torque). This is the best overall starting method when costs are considered.

9) If hydraulic conditions during pump start-up (water surge) or shutdown (water hammer) warrant the extra expense, specify Soft Start or Variable Speed with Soft Starting in the bypass mode.

10) If voltage drop due to large cables warrant the extra cost, specify Auto transformer Starting.

For a complete chart of starting parameters, including starting currents and starting power (kilowatts) see

http://mastercontrols.com/EngInfo/Articles/Nasby/Motor-Starting-Parameters_WP0.pdf

Please feel free to contact us if you have any questions on any of the above.

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File: Wye-Delta_Starting_White_Paper.pdf

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