TYPE 656: VARIABLE SPEED PUMP

General Description

Type656, donated to the standard TRNSYS Library with the release of TRNSYS v. 16, models a variable speed pump that is able to maintain any outlet mass flow rate between zero and a rated value. The mass flow rate of the pump varies linearly with control signal setting. Pump power draw, however, is modeled using a polynomial. Pump starting and stopping characteristics are not modeled, nor are pressure drop effects. As with most pumps and fans in TRNSYS, Type656 takes mass flow rate as an input but ignores the value except in order to perform mass balance checks. Type656 sets the downstream flow rate based on its rated flow rate parameter and the current value of its control signal input.

Nomenclature

$\dot{Q}_{fluid}$	[kJ/hr]	Energy transferred from the pump motor to the fluid stream passing through the pump.
η_{motor}	[0..1]	Pump motor efficiency
$\eta_{overall}$	[0..1]	Overall pump efficiency (motor efficiency * pumping efficiency)
$\eta_{pumping}$	[0..1]	Efficiency of pumping the fluid
$f_{motorloss}$	[0..1]	Fraction of pump motor inefficiencies that contribute to a temperature rise in the fluid stream passing through the pump. The remainder of these inefficiencies contribute to an ambient temperature rise.
$\dot{P}_{rated}$	[kJ/hr]	Rated power of the pump.
$\dot{P}$	[kJ/hr]	Power drawn by the pump at the current time.
$\dot{P}_{shaft}$	[kJ/hr]	Shaft power required by the pumping process (does not include motor inefficiency)
$a_0, a_1, a_2 \ldots$	[-]	Polynomial coefficients in the pump power curve
γ	[0..1]	Pump control signal.
$\dot{Q}_{ambient}$	[kJ/hr]	Energy transferred from the pump motor to the ambient air surrounding the pump.
$T_{fluid,out}$	[kJ/kg]	Temperature of fluid exiting the pump
$T_{fluid,in}$	[kJ/kg]	Temperature of fluid entering the pump
$\dot{m}_{fluid}$	[kg/hr]	Mass flow rate of fluid passing though the pump.

Detailed Description

If the pump is determined to be off due to it's control signal being set equal to 0, the Type656 pump mass flow rate, power drawn, energy transferred from the pump to ambient and energy transferred from the pump to the fluid stream are all set to zero. The temperature of fluid exiting the pump under the OFF condition is set to the temperature of fluid at the pump inlet. If, however, the pump is determined to be ON (control signal greater than 0) then the power drawn by the pump is determined using equation 656.1.

$$\dot{P} = \dot{P}_{rated}\left(a_0 + a_1\gamma + a_2\gamma^2 + a_3\gamma^3 + a_4\gamma^4 + \ldots\right) \quad \text{(Eq. 656.1)}$$

The mass flow rate of fluid exiting the pump is a linear function of the control signal with a control signal of 1 resulting in the pump delivering its rated mass flow. The efficiency of pumping the fluid from its inlet to its outlet pressure is given by equation 656.2; both the motor and overall efficiency of the pump are entered by the user as inputs to the model.

$$\eta_{pumping} = \frac{\eta_{overall}}{\eta_{motor}} \quad \text{(Eq. 656.2)}$$

The shaft power of the pump can now be calculated. The shaft power is the power required to perform the pumping operation, excluding the effects of motor inefficiency.

$$\dot{P}_{shaft} = \dot{P}\,\eta_{motor} \quad \text{(Eq. 656.3)}$$

Energy transferred from the pump motor to the fluid stream is calculated as shown in equation 656.4

$$\dot{Q}_{fluid} = \dot{P}_{shaft}\left(1-\eta_{pumping}\right)+\left(\dot{P}-\dot{P}_{shaft}\right)f_{motorloss} \quad \text{(Eq. 656.4)}$$

In which $\eta_{pumping}$ is the pumping process efficiency and $f_{motorloss}$ is a value between 0 and 1 that determines whether the pump motor inefficiencies cause a temperature rise in the fluid stream that passes through the pump or whether they cause a temperature rise in the ambient air surrounding the pump. Through use of the $f_{motorloss}$ fraction, the user can in effect specify whether the pump has an inline motor, in which case all waste heat would impact the fluid stream temperature and $f_{motorloss}$ would have a value of 1, or whether the pump motor is housed outside of the fluid stream such that it's waste heat impacts the ambient and $f_{motorloss}$ would have a value of 0.

The energy transferred from the pump motor to the ambient is given by equation 656.5.

$$\dot{Q}_{ambient} = \left(\dot{P}-\dot{P}_{shaft}\right)\left(1-f_{motorloss}\right) \quad \text{(Eq. 656.5)}$$

The temperature of fluid exiting the pump can now be calculated as shown in equation 656.6.

$$T_{fluid,out} = T_{fluid,in} + \frac{\dot{Q}_{fluid}}{\dot{m}_{fluid}} \quad \text{(Eq. 656.6)}$$

Type656 does not model pump starting and stopping characteristics. As soon as the control signal indicates that the pump should be ON, the outlet flow of fluid jumps to the appropriate value between 0 and its rated condition. The reasoning is that the time constants with which pumps react to control signal changes is shorter than the typical time steps used in hydronic simulations. Type656 also operates as many pump and fan models do in TRNSYS. That is to say that they ignore the fluid mass flow rate provided as an input to the model except so as to perform a mass balance on the pump. Therefore care must be taken in specifying fluid loops with multiple pumps that inlet mass flow rates greater than the rated mass flow rate for a given pump are not specified. The total number of time steps during which the fluid inlet mass flow rate for Type656 is not equal to its outlet flow rate is reported to the list file at the end of each simulation.