Quad Tank Control Bonsai Brain

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Brain Design

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1.0 Process Description and Control Strategy

A quad tank simulation has been built with VP Link. There are two variable speed pumps Pump#1 and Pump#2 which supply liquid from a common reservoir to four tanks. Pump#1 supplies liquid to Tank#1 and Tank#4 through a two-way valve Gamma1. Pump#2 supplies liquid to Tank#2 and Tank#3 through a two-way valve Gamma2.

The liquid from Tank#3 is continuously drained from the bottom via gravity flow to Tank#1 which then drains from Tank#1 to the common reservoir. Similarly the liquid from Tank#4 is continuously drained into Tank#2 which drains to the common reservoir.

As each pump flows into two tanks, which then drain into other tanks both pumps can impact the level in all the tanks in complex ways. If Pump#1 tries to control the level in Tank#1 by varying its speed in this process, it also varies the flow going to Tank#4. This in turn disturbs the level of liquid in Tank#2. Similarly Pump#2 tries to control the level in Tank#2 by varying its speed. But in this process, it also varies the flow going to Tank#3. This in turn disturbs the level of liquid in Tank#1.

The control strategy is to maintain specified level (at the setpoint) in Tank#1 and Tank#2 by varying the pump speeds.

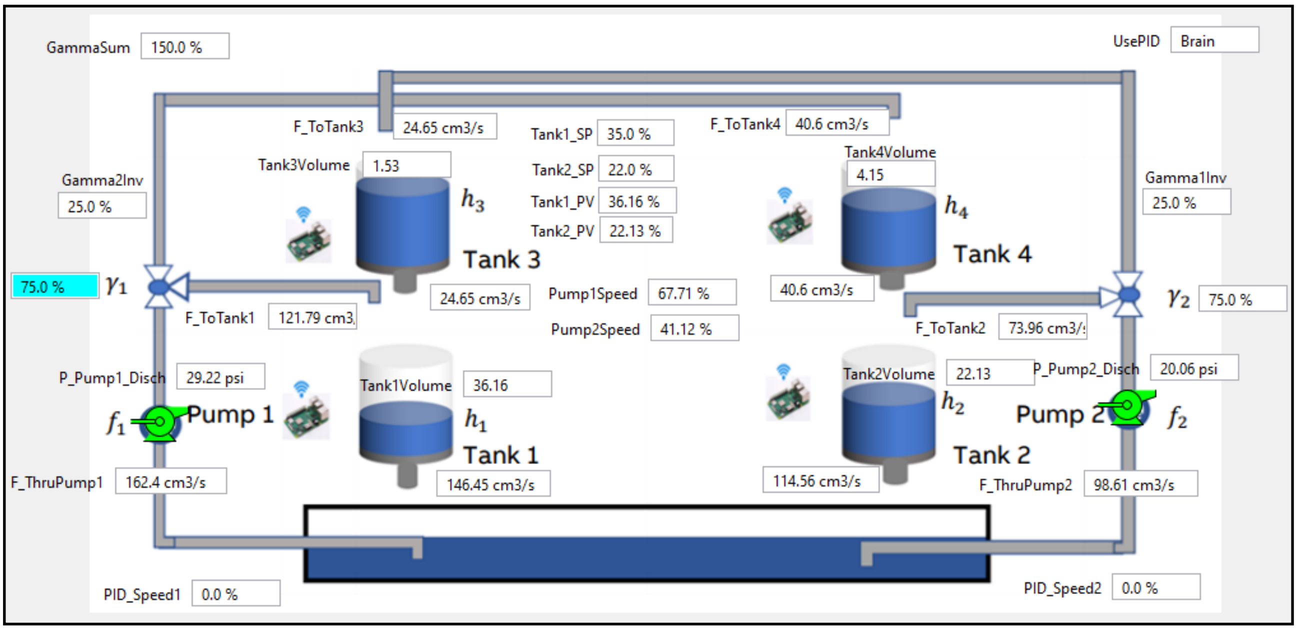

Figure 1-1: Quad Tank Schematic

2.0 State Space

Below are the State and Actions tags that would be defined in the Bonsai Brain.

Table 2-1: State and Action Tags

State Tags	Action Tags
• Tank#1 Volume in % (Tank1_PV) • Tank#2 Volume in % (Tank2_PV) • Tank#3 Volume in % (Tank3_PV) • Tank#4 Volume in % (Tank4_PV) • Tank#1 Level Setpoint in % (Tank1_SP) • Tank#2 Level Setpoint in % (Tank2_SP) • Two-way valve downstream of Pump 1 (Gamma1) • Two-way valve downstream of Pump 2 (Gamma2) • Sum of Gamma1 and Gamma2 (GammaSum)	• Pump#1 Speed (Pump1Speed) • Pump#2 Speed (Pump2Speed)

Gamma1 = Gamma2 = 75%

3.0 Model Description

The quad tank model is focused on the flow around a closed loop system. As such the most important factor in this model is the flow network and the valves, pumps and tanks that are included within it.

The tags that execute the Liquid Flow Network are built by a VP Link tool called LFNGEN. A Liquid Flow network is made up of pressure nodes and flow links between those nodes. Pressure nodes have no liquid holdup and have a design pressure. Flow links connect two pressure nodes and represent a design flow rate between the two pressure nodes. These flow links essentially provide a resistance to flow and may or may not have a variable resistance (=control valve) in the line. Also flow links can have block valves in the line that completely block the flow. In the Excel sheet, the user specifies pressure nodes and flow links between those nodes. In addition, a tank can be specified that acts like a pressure node.

Pressure nodes are endpoints for the Flow Links. They have a design pressure. Normally the pressure in these pressure nodes will vary during the course of the simulation as flows increase and decrease, but the pressure of the atmosphere is a constant for this simulation. Hence its calculation is overridden with the "=TrackPVE(14.7)" specification. This will be converted to a VP Link algorithm, "TrackPVE", and the Parameters for that tag will be 14.7; this fixes the value of the atmospheric pressure at 14.7.

The Flow Tag section defines the links between pressure nodes. These are typically pipes with zero or control valve and multiple block valves. If there is a control valve in the line, it is specified in the Valve Tag column. Then the source and sink pressure nodes are listed in the UpStreamP and DownStrmP columns. Any tags one put in these two columns must exist either in the Pressure Node section or the Level Tag section. Since we are setting up a resistance to flow in this link, we also need to specify the flow that goes through this pipe from the upstream design pressure to the downstream design pressure, it is specified in the FlowThruVlv column. One needs to know how much the valve is open (i.e. its design opening) when the design flow is achieved, it is specified in the DesignValvePos column. Finally, one needs to know if there are any block valves in the line that will completely block the line if they are not open. This is the "Conditions" column. If any condition is zero, then the flow is blocked in that line.

In the generated LFN diagram, pressure nodes are ovals, tanks with a fixed pressure are rectangles, solid lines are calculated by the network, and dashed lines are set by the user.

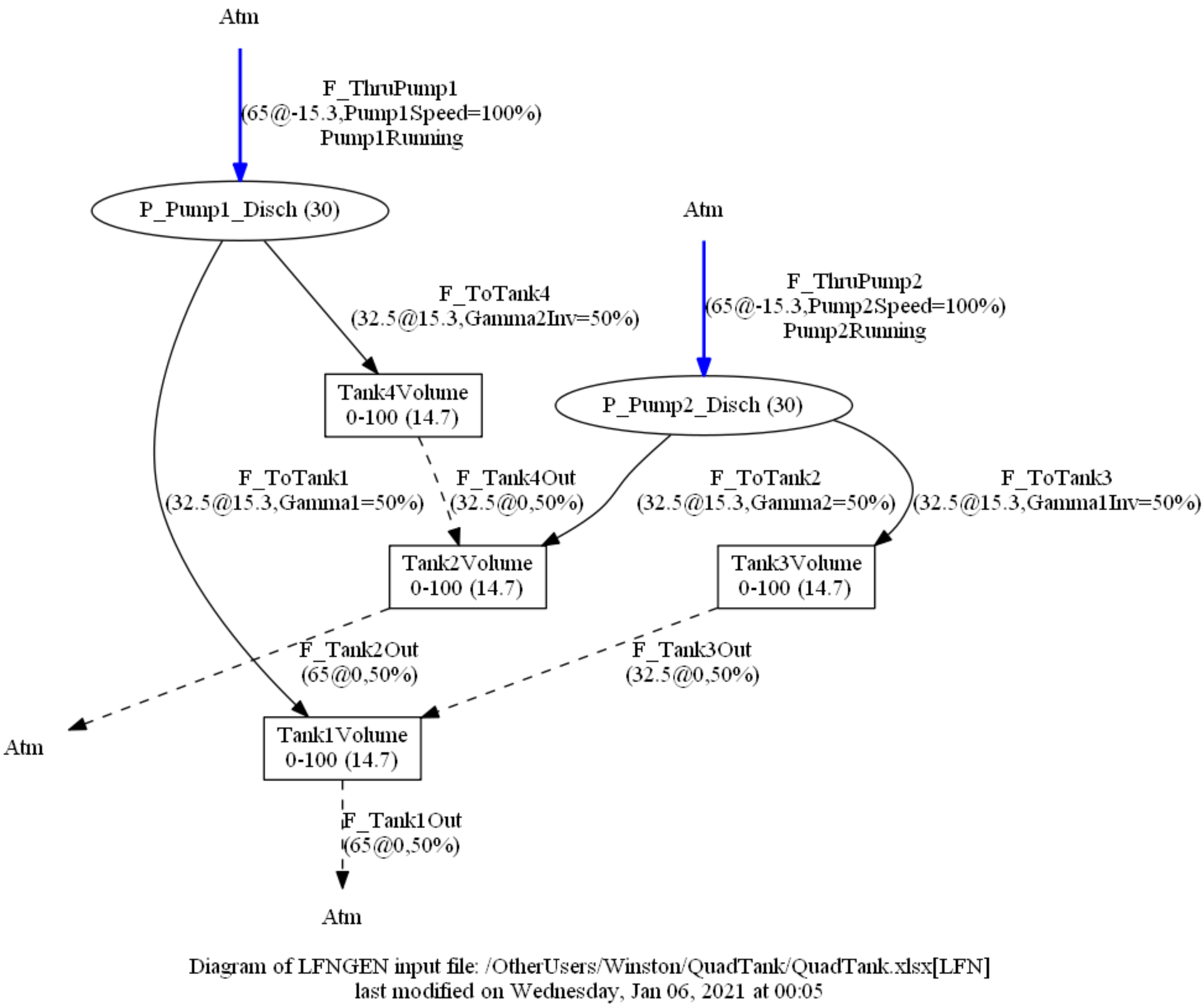

Figure 3-1: LFN Diagram

The flow tag for the Pump#1 starts at Atm (Atmospheric pressure) and flows to the P_Pump1_Disch. From the P_Pump1_Disch pressure node two flows emerge, one to Tank1Volume, and the other to Tank4Volume. These flow rate to Tank#1 is regulated by Gamma1 and that to Tank #4 is regulated by Gamma2Inv. Finally, the drain flow tags are specified so that liquid can flow out the bottom of Tank #3 to Tank #1 and Tank #1 to the atmosphere.

The flow tag for the Pump#2 starts at Atm (Atmospheric pressure) and flows to the P_Pump2_Disch. From the P_Pump2_Disch pressure node two flows emerge, one to Tank2Volume, and the other to Tank3Volume. These flow rate to Tank#2 is regulated by Gamma2 and that to Tank #3 is regulated by Gamma1Inv. Finally, the drain flow tags are specified so that liquid can flow out the bottom of Tank #4 to Tank #2 and Tank #2 to the atmosphere.

Since the flow rate of the drains do not follow the normal equation using the upstream pressure and the downstream pressure, one can override their calculation with the available built-in algorithm for gravity flow, "CFlowOut".

The liquid flow network tags are modelled following design parameters: the variable speed pump Pump#1 can pump out 293cm^3/s, at its maximum speed. At this point, the discharge pressure of the pump will be 35.7 psia and the flow to Tank#1 is 195.3cm^3/s and flow to Tank#4 is 97.6cm^3/s. At these conditions, valves the Gamma1 is at 100% and Gamma2Inv at 50%. The variable speed pump Pump#2 can pump out 293cm^3/s, at its maximum speed. At this point, the discharge pressure of the pump will be 35.7 psia and the flow to Tank#2 is 195.3cm^3/s and flow to Tank#3 is 97.6cm^3/s. At these conditions, valves the Gamma2 is at 100% and Gamma1Inv at 50%. The capacity of each tank is 8835cm^3.

The speed of the two pumps Pump#1 and Pump#2 are controlled/varied by PID controllers OR by Bonsai Brain to maintain the levels of in Tank#1 and Tank#2 at their respective setpoints.