

How not to run fans in parallel

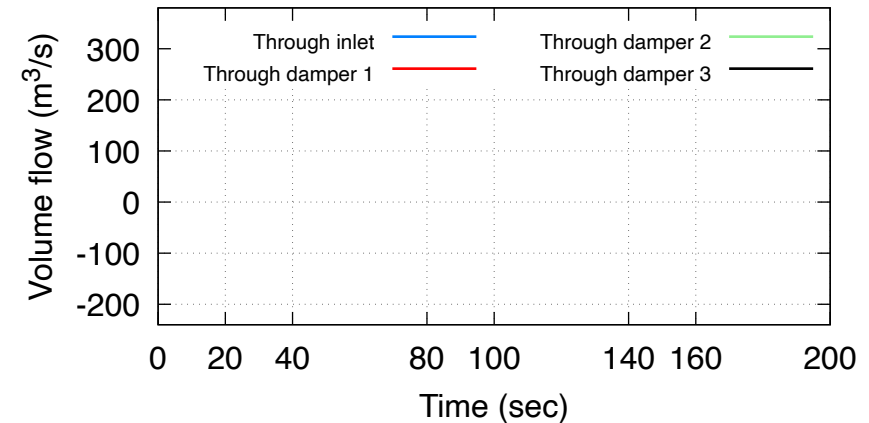
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Consider three identical fans with isolation dampers, in parallel: The fans have a Q - P_{tot} characteristic with a bad stall hump.

The fans are started sequentially. Fans 1 and 2 get to suitable parts of their characteristics. Fan 3 can't get out of stall.



Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

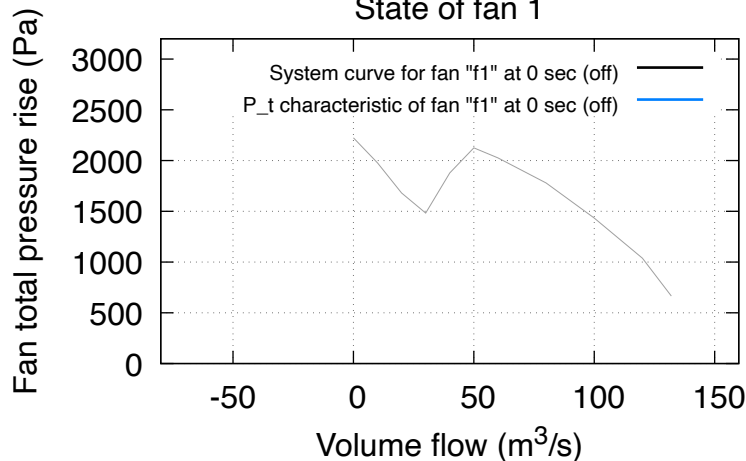
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

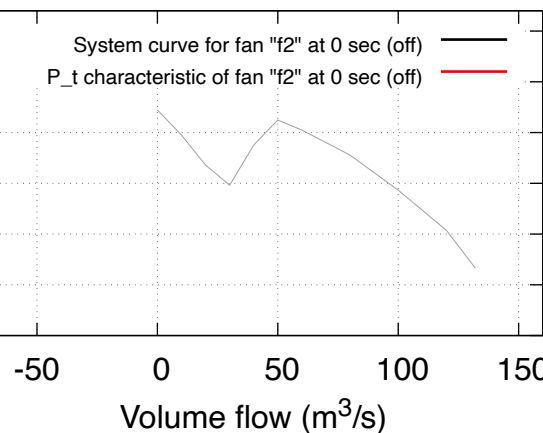
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

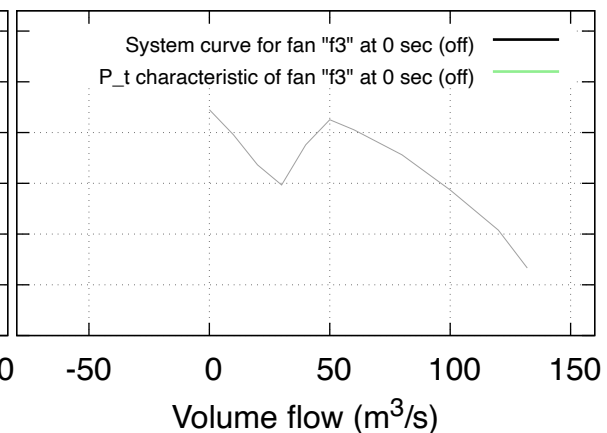
State of fan 1



State of fan 2



State of fan 3



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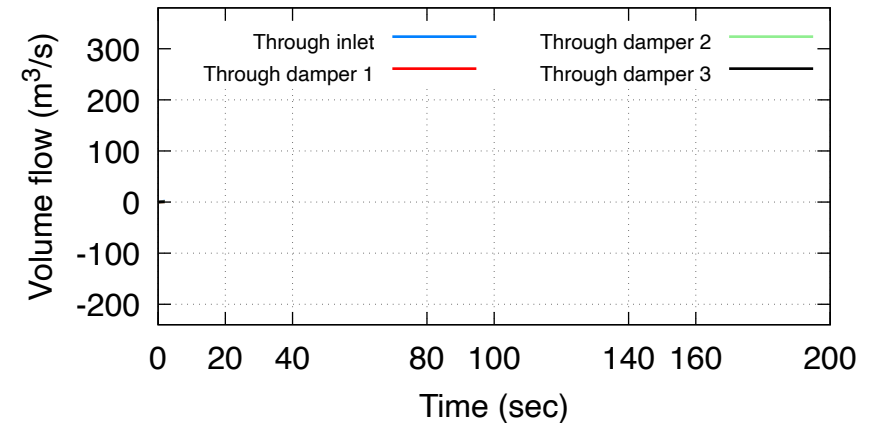
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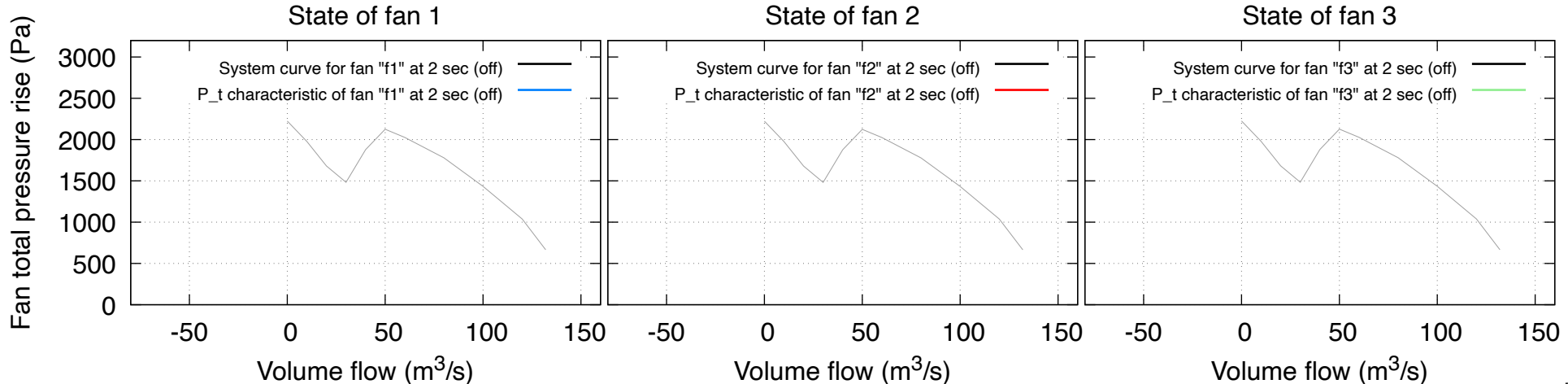
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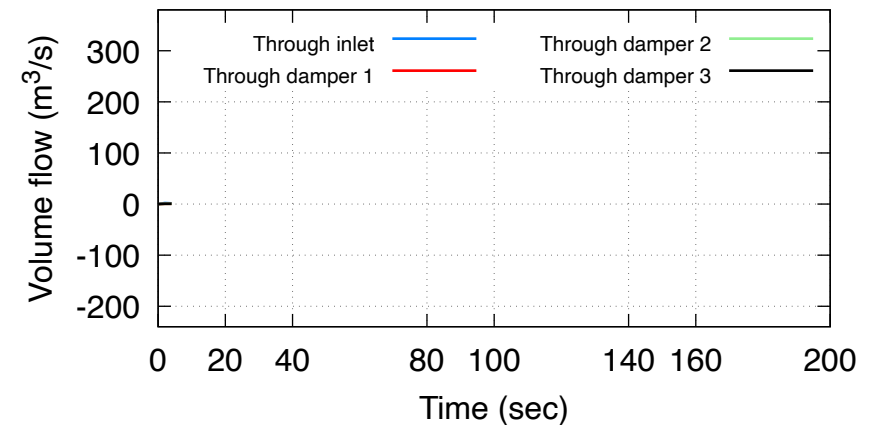
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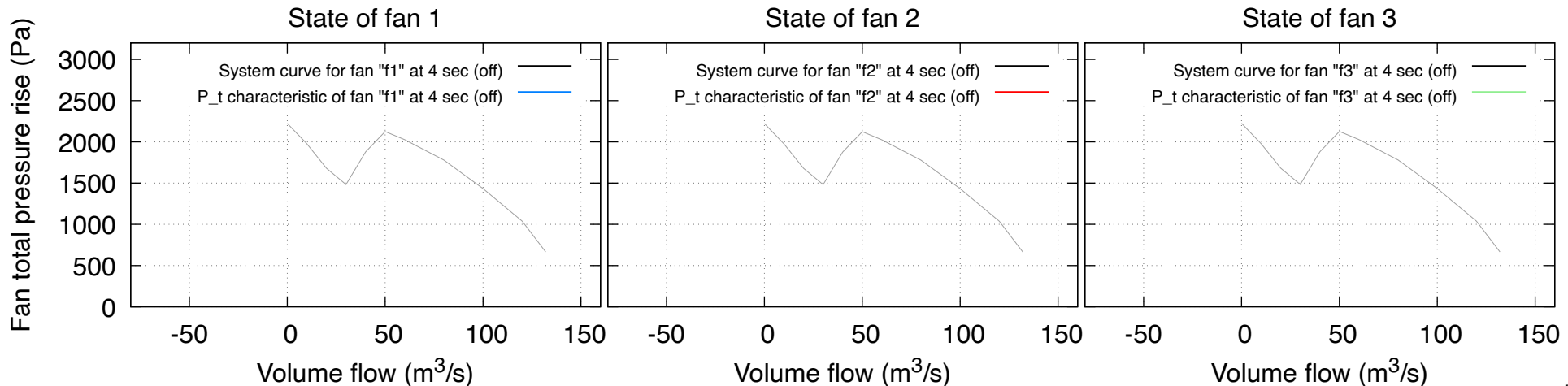
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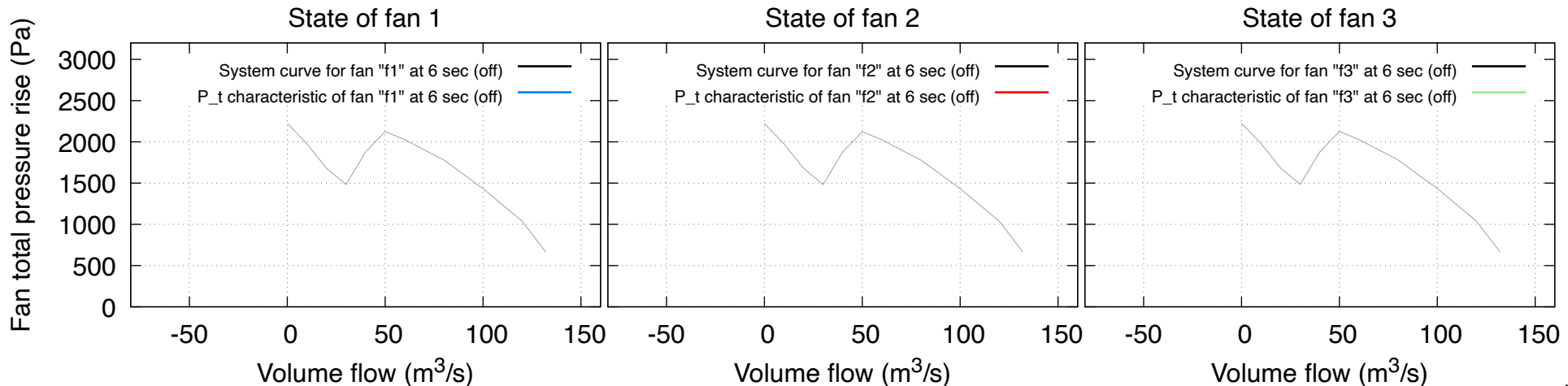
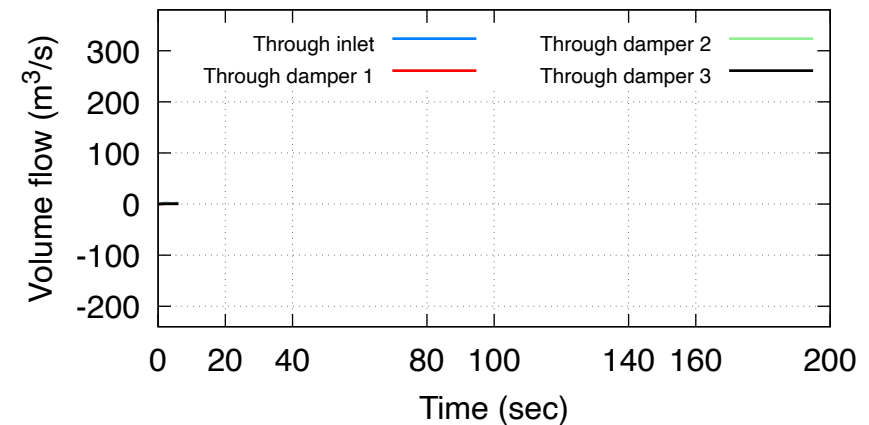
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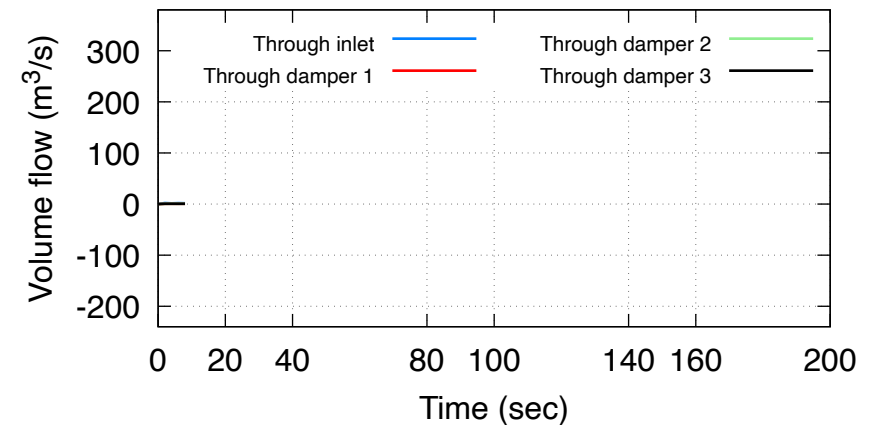
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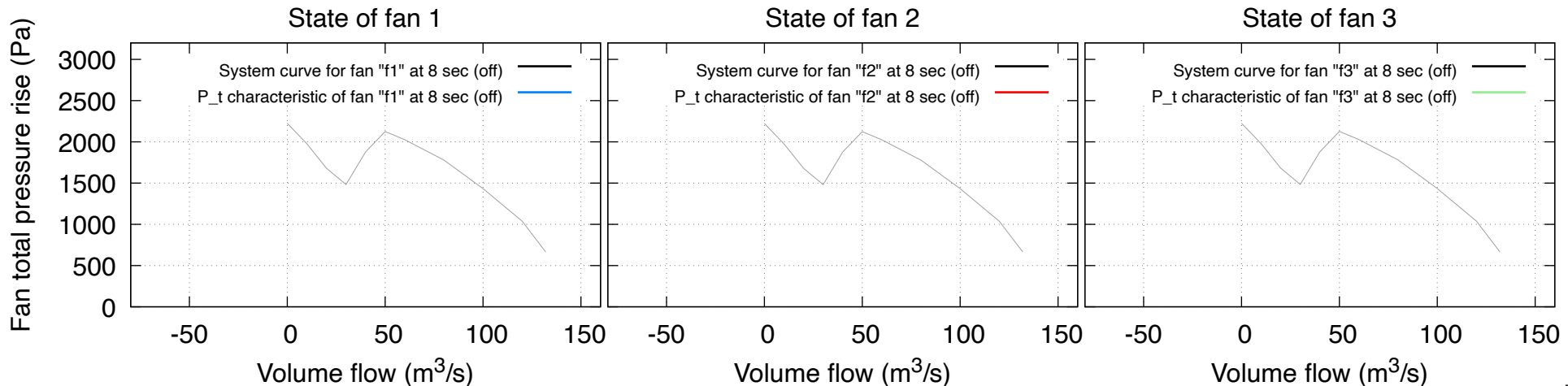
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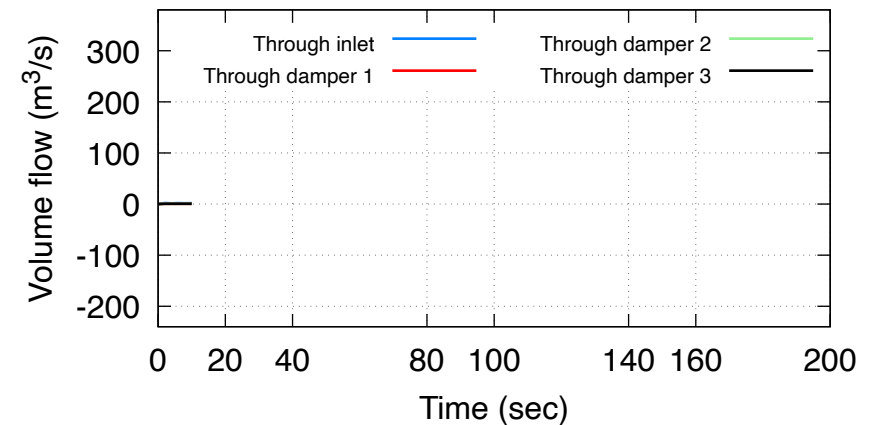
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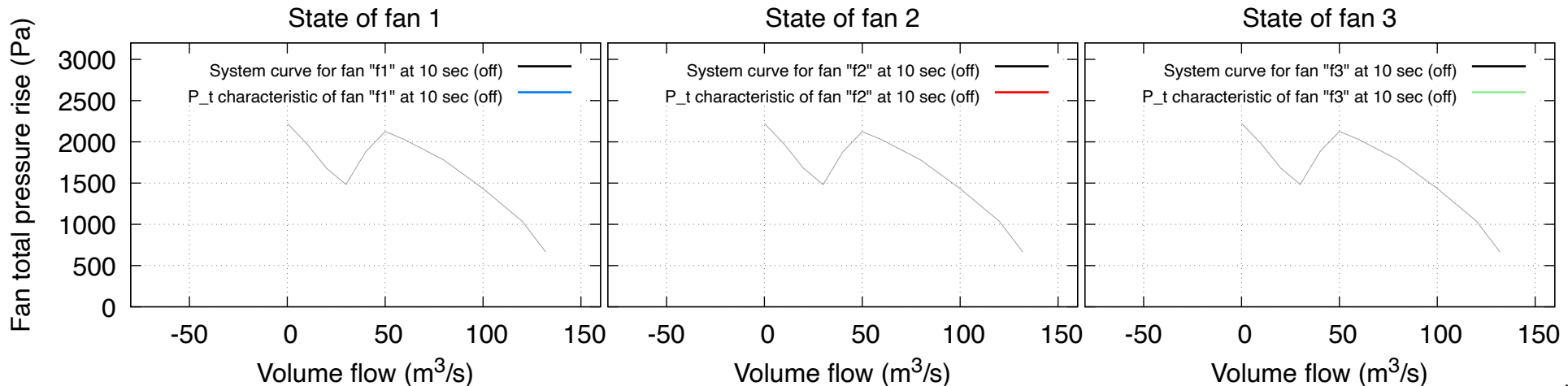
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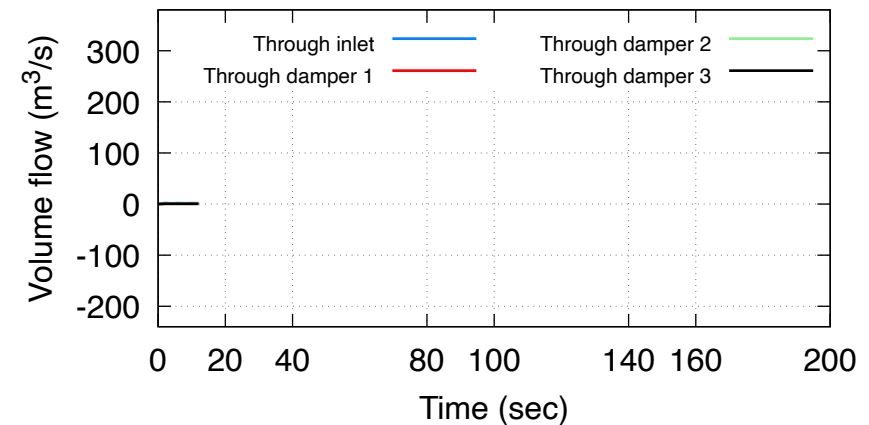
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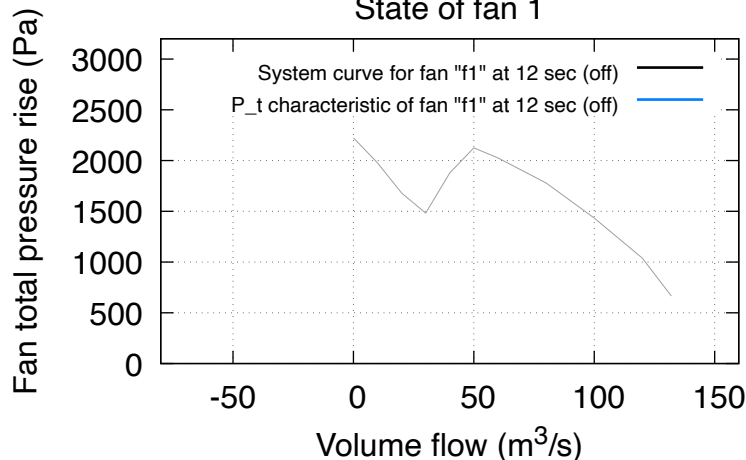
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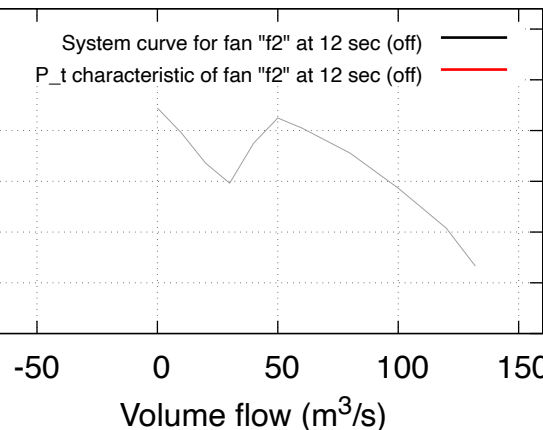
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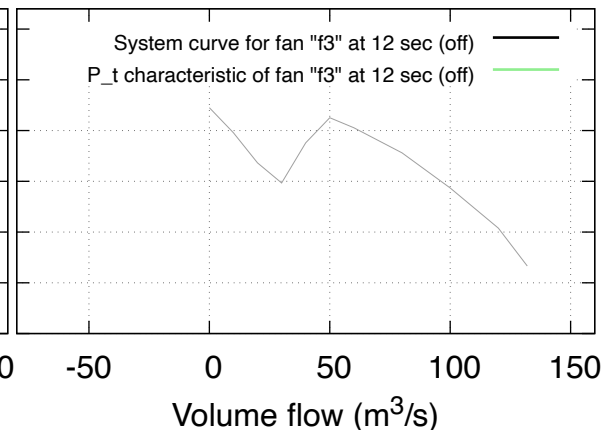
State of fan 1



State of fan 2



State of fan 3



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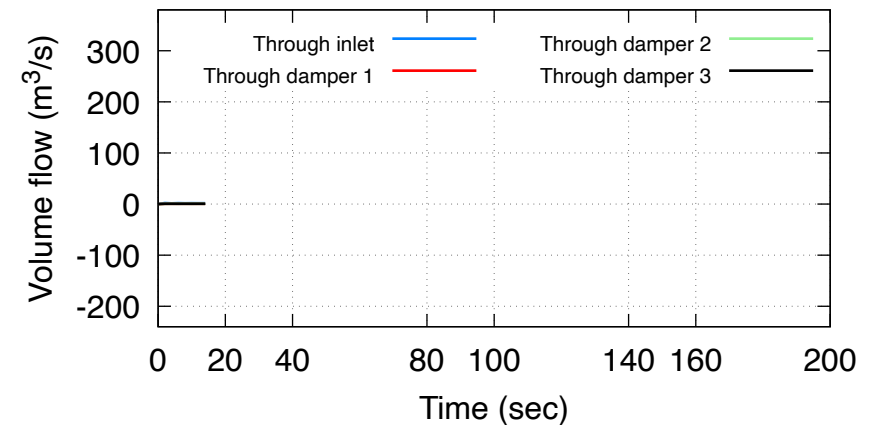
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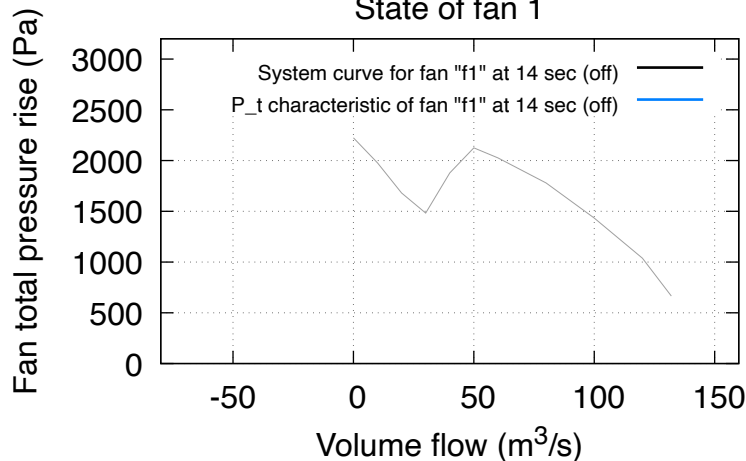
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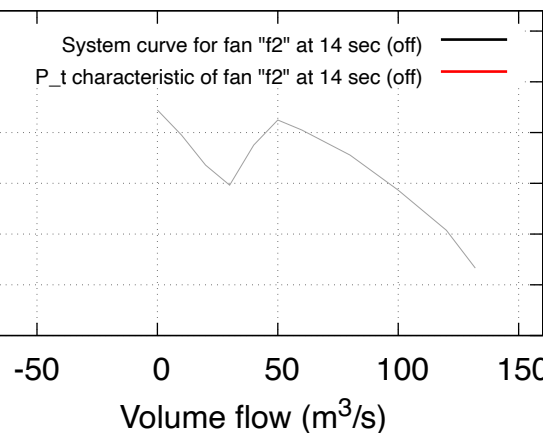
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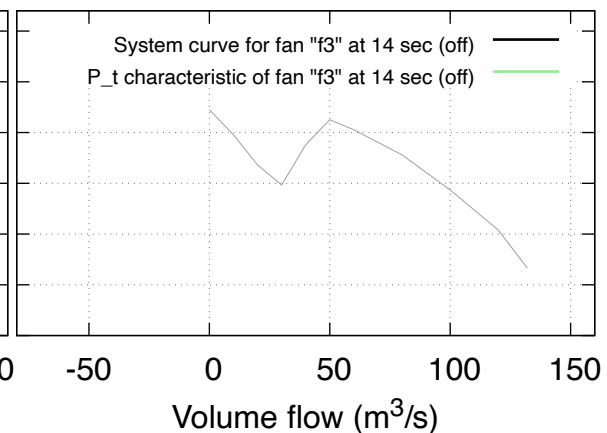
State of fan 1



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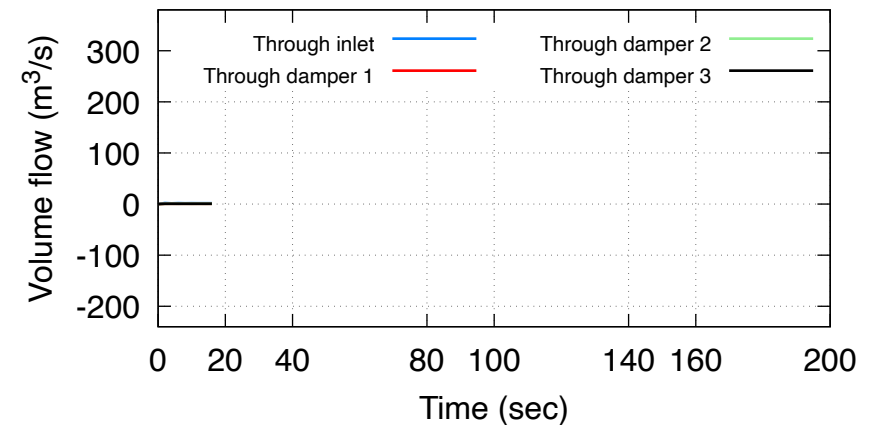
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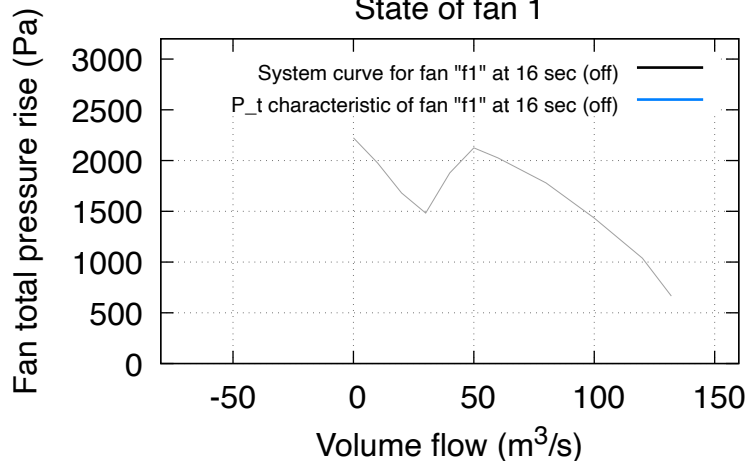
At 80 seconds, damper 2 opens

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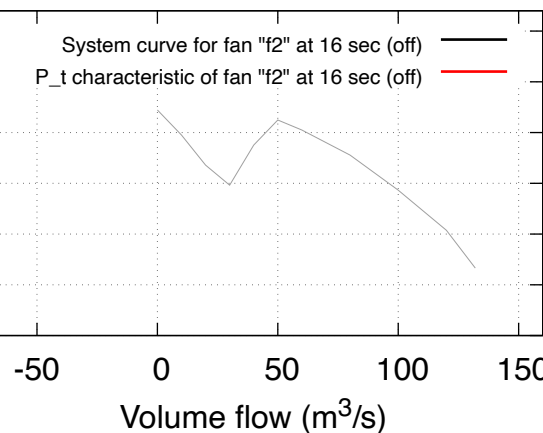
At 140 seconds, damper 3 opens

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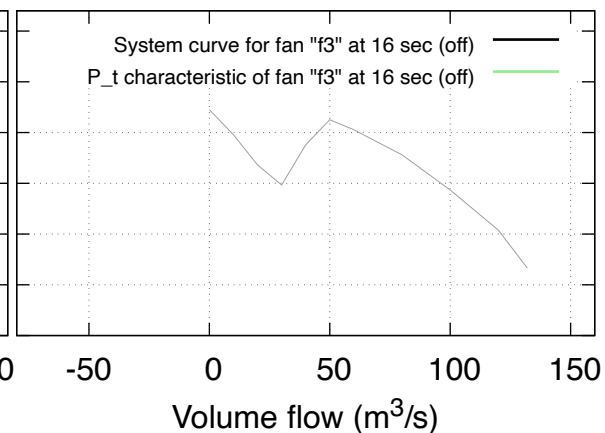
State of fan 1



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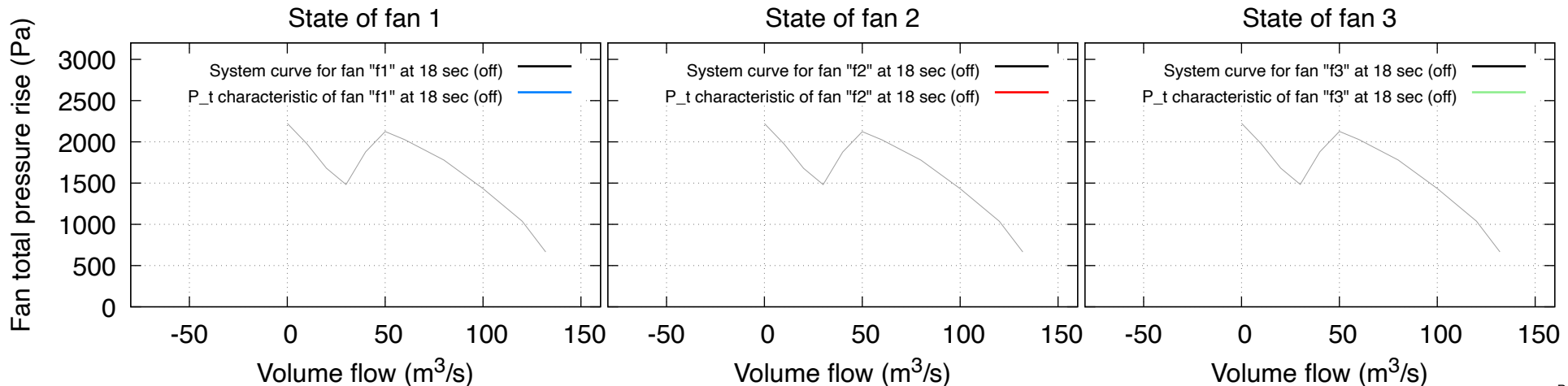
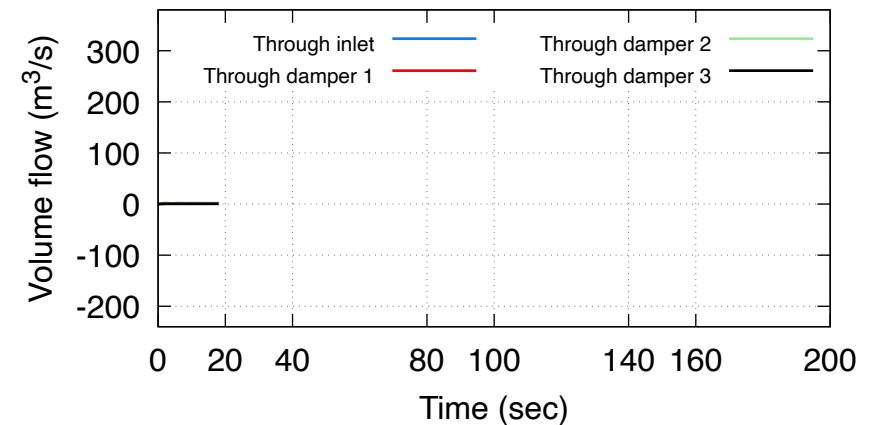
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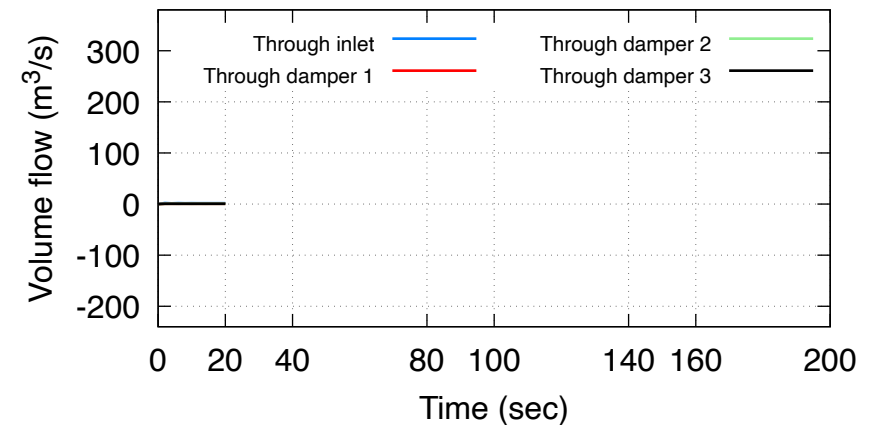
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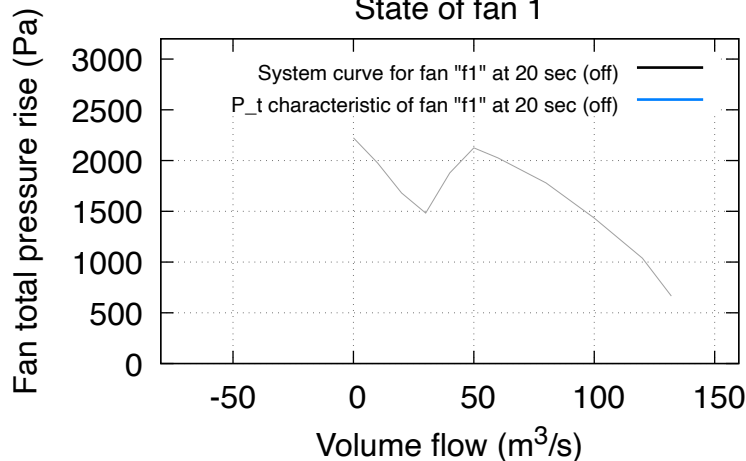
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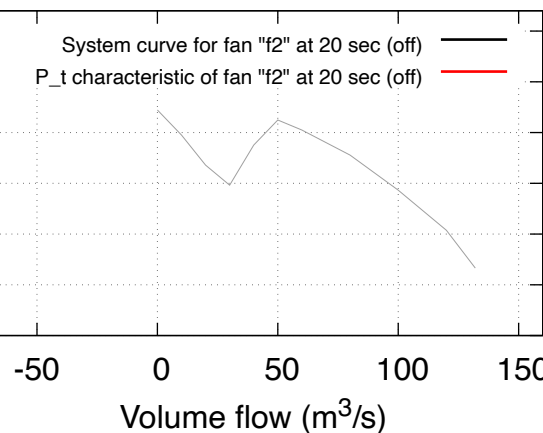
At 140 seconds, damper 3 opens

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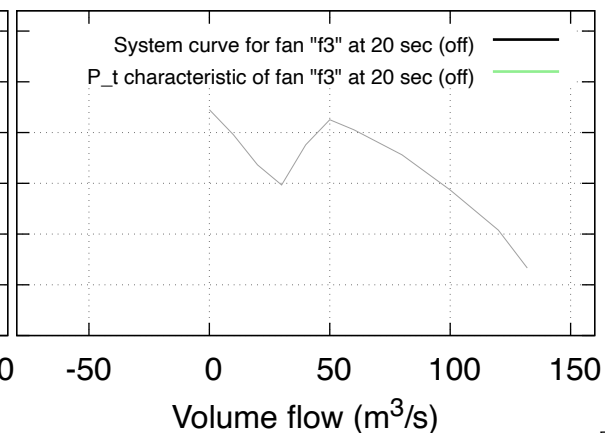
State of fan 1



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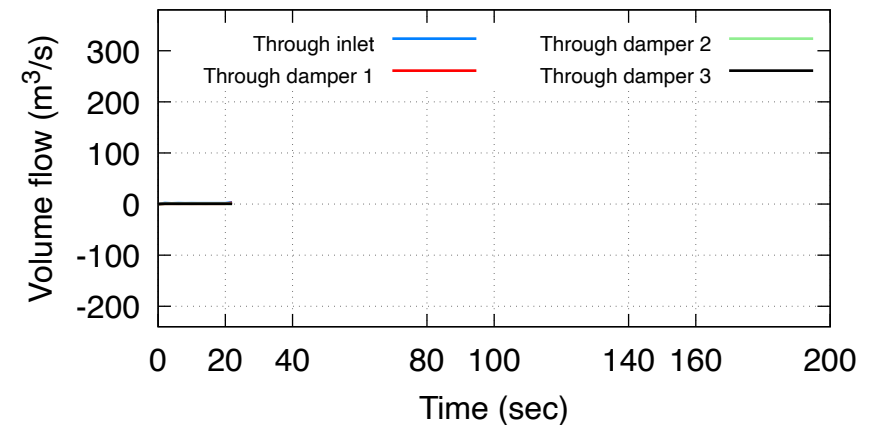
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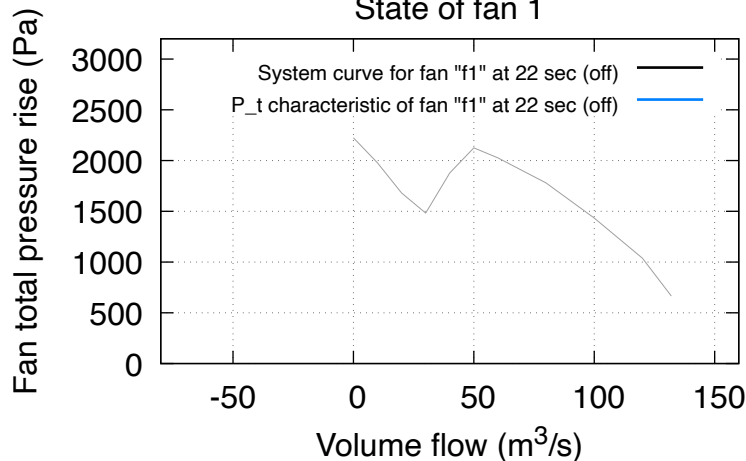
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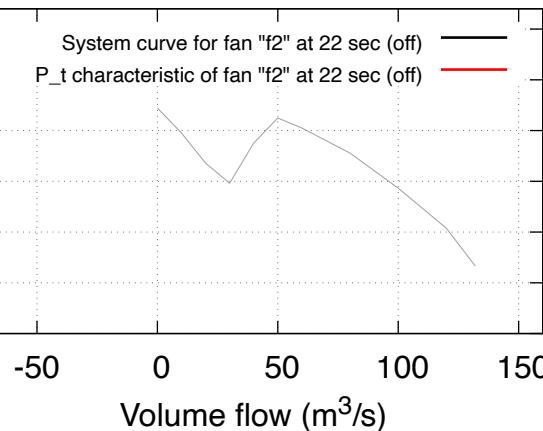
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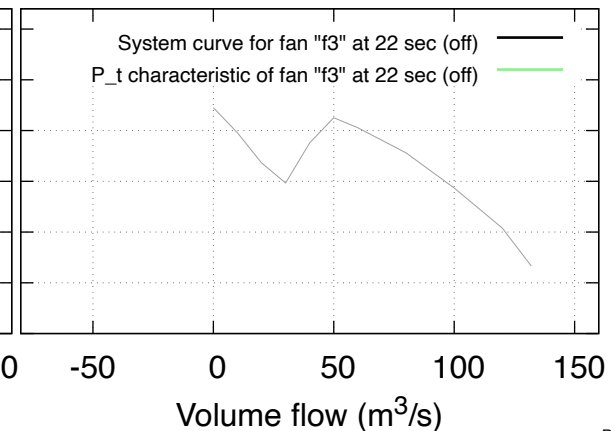
State of fan 1



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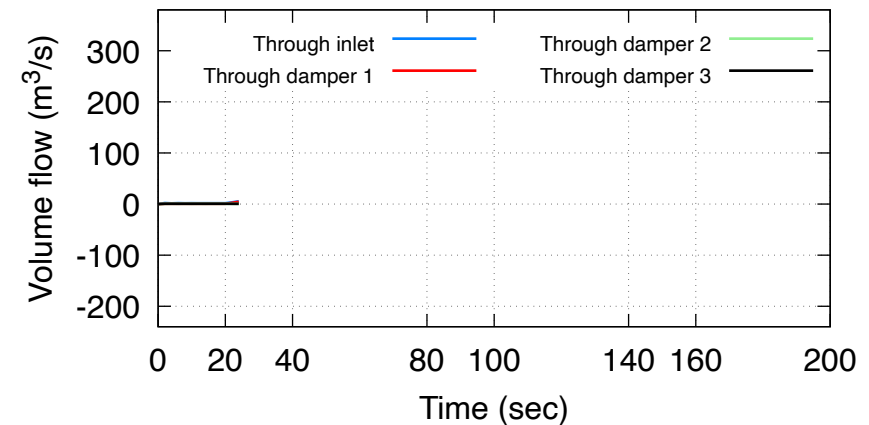
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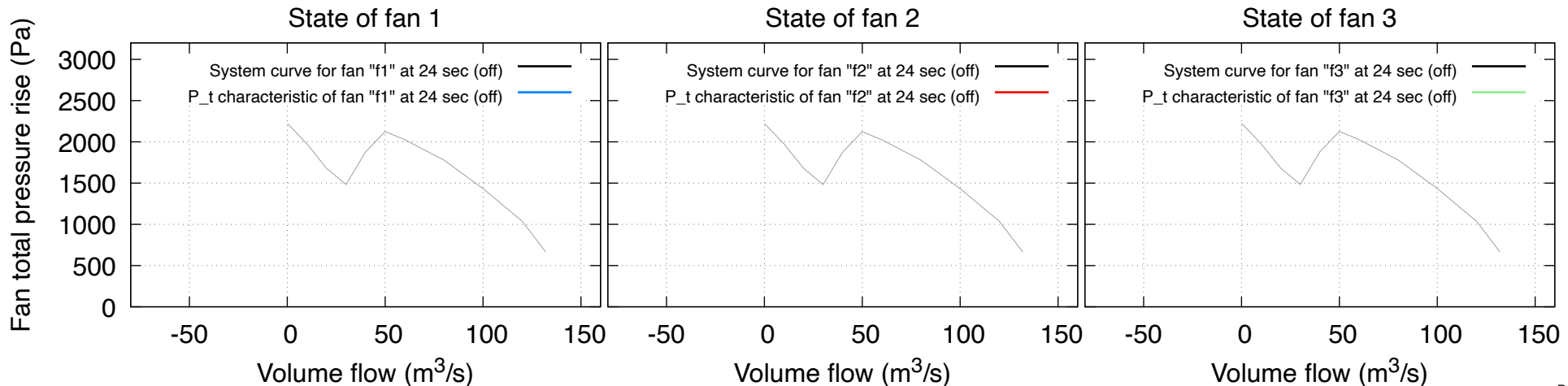
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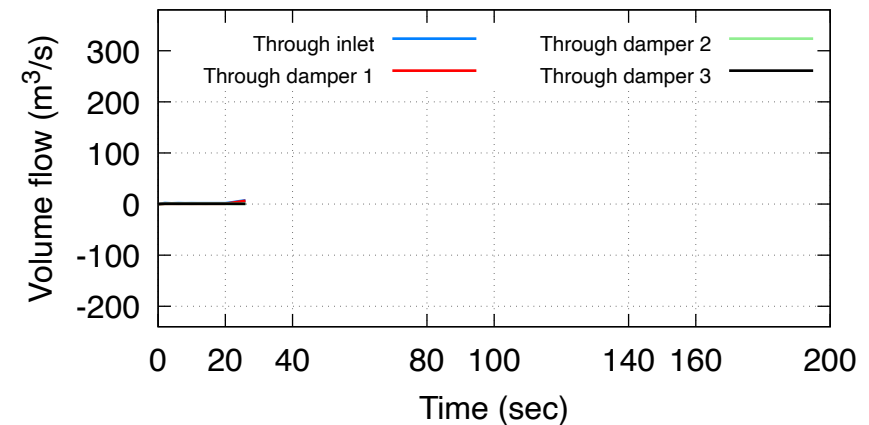
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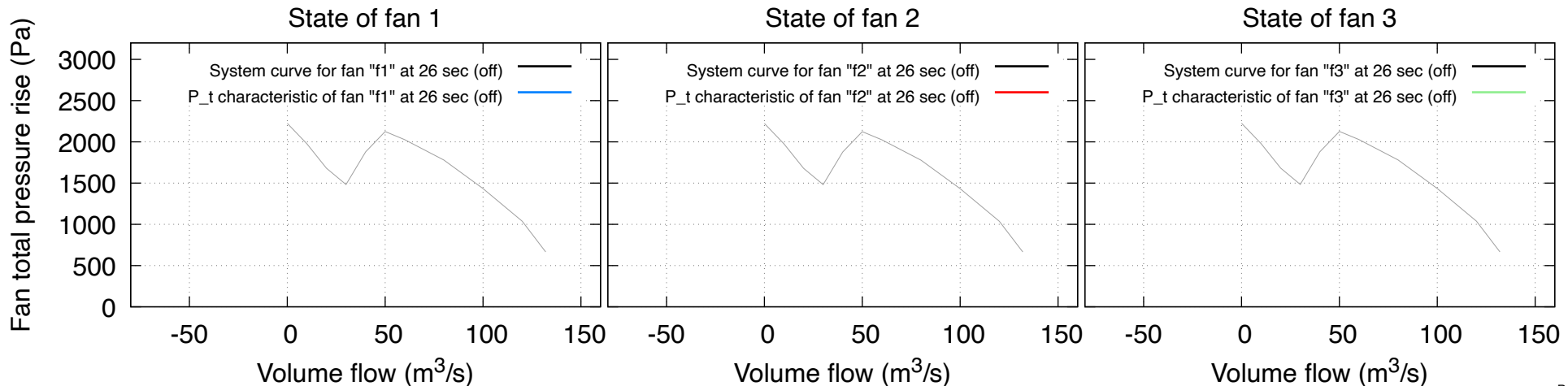
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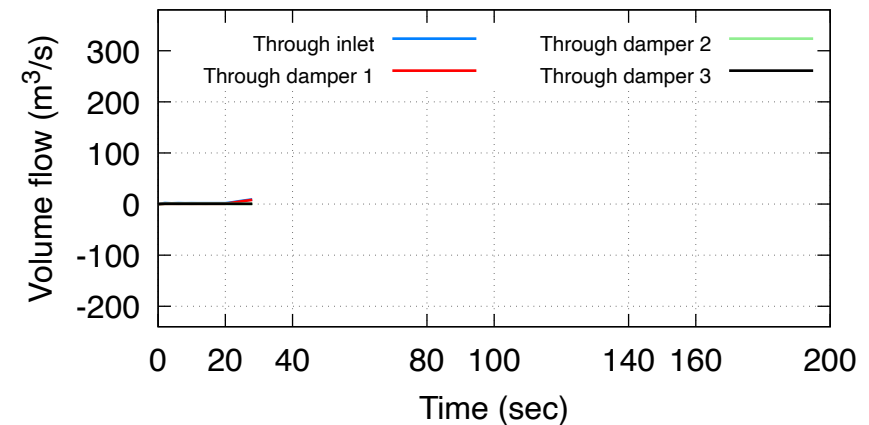
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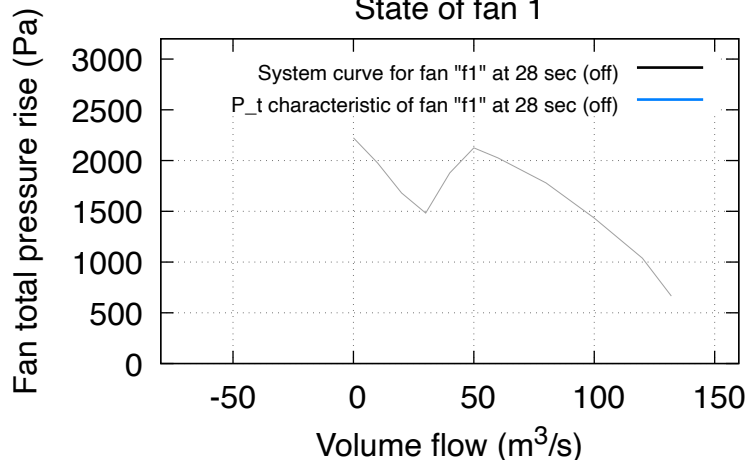
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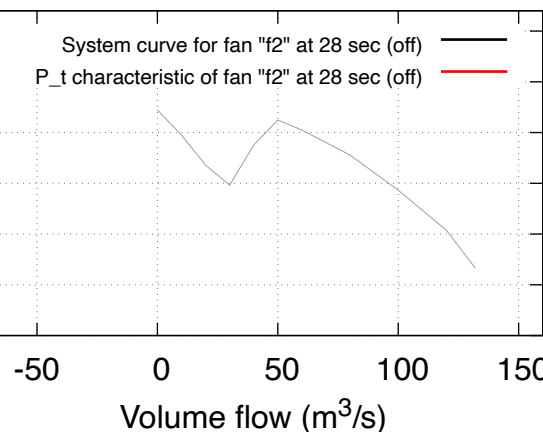
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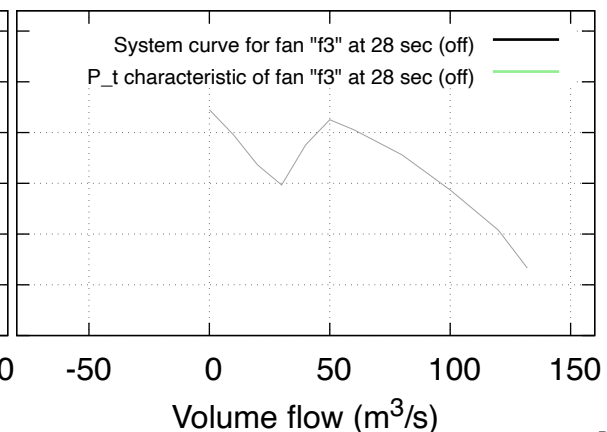
State of fan 1



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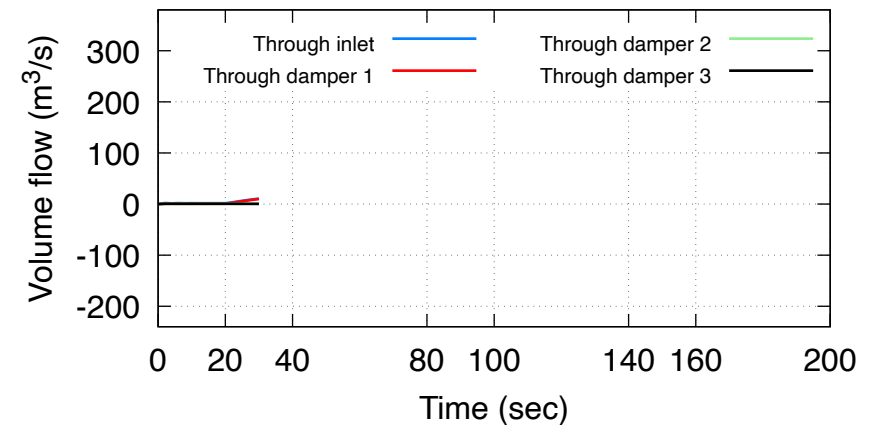
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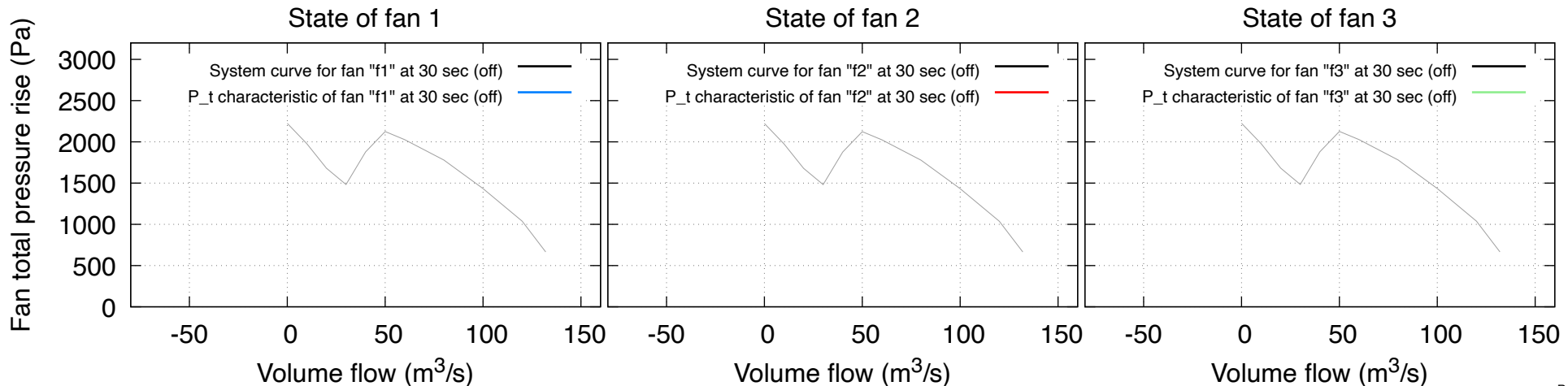
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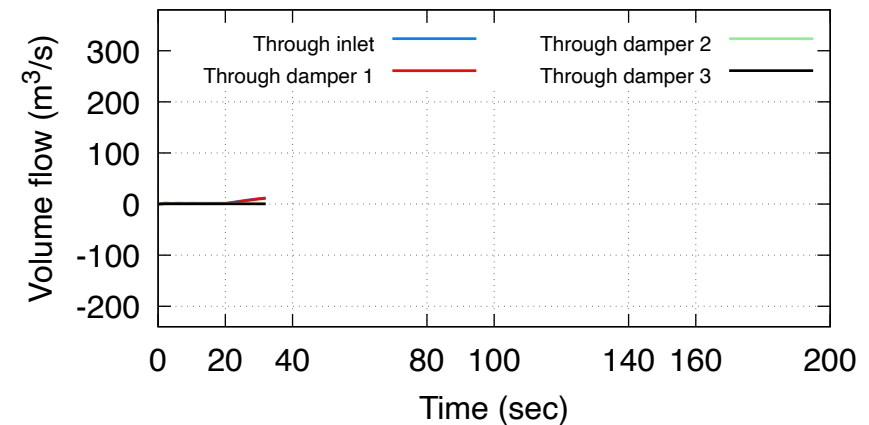
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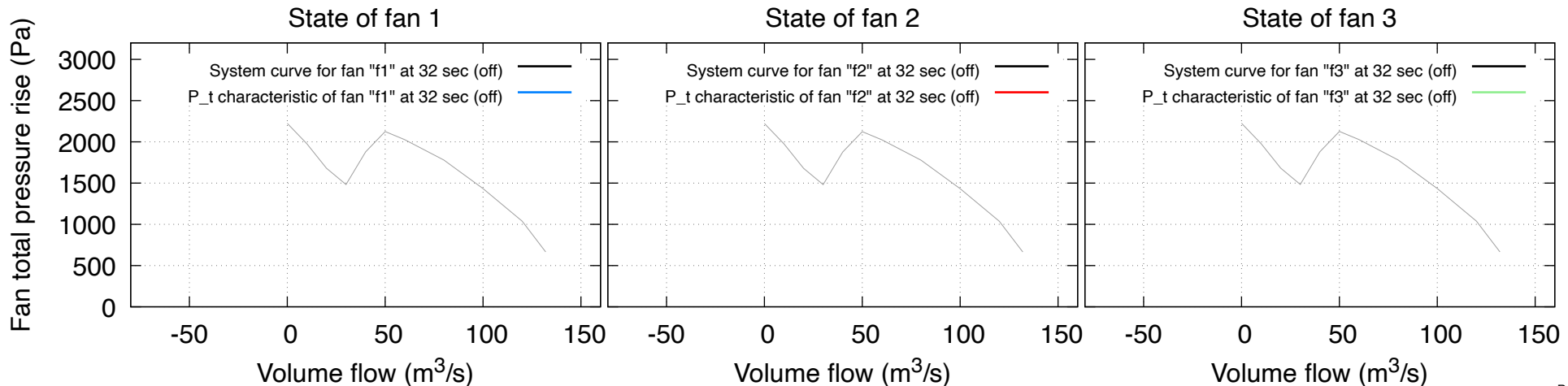
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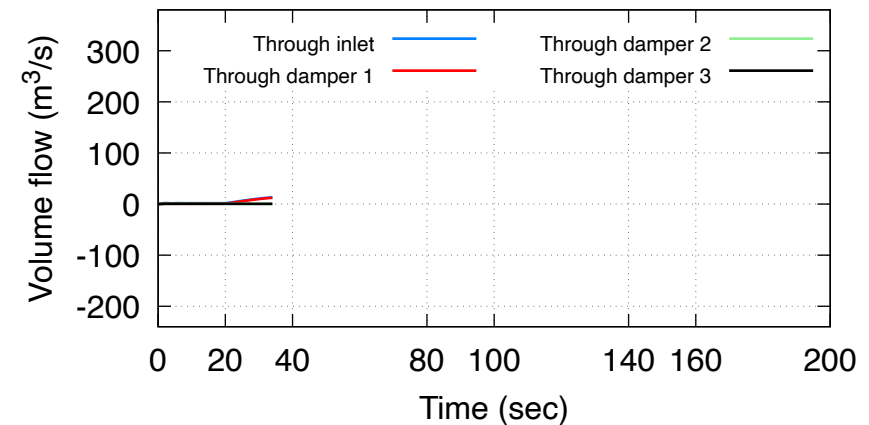
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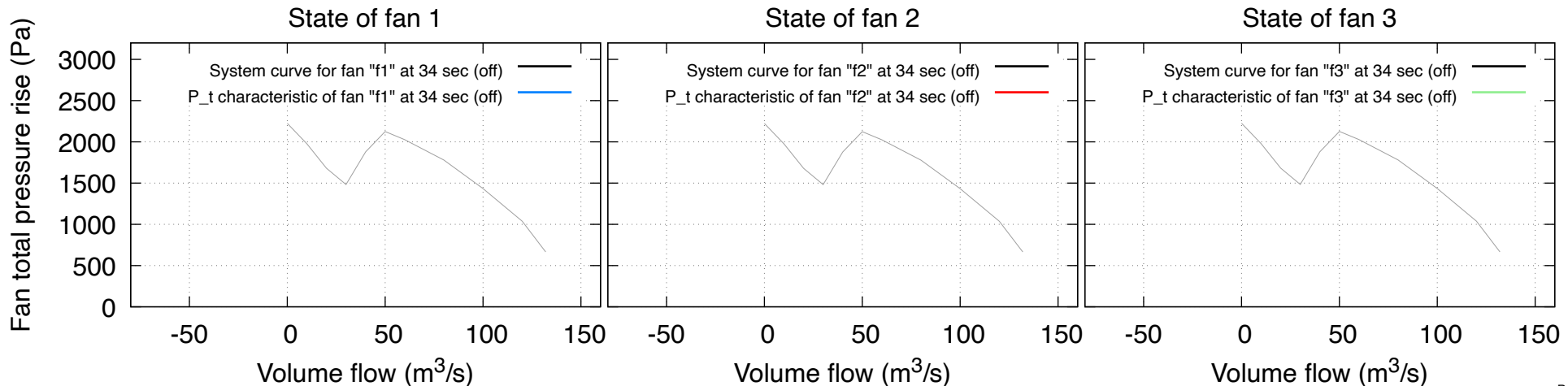
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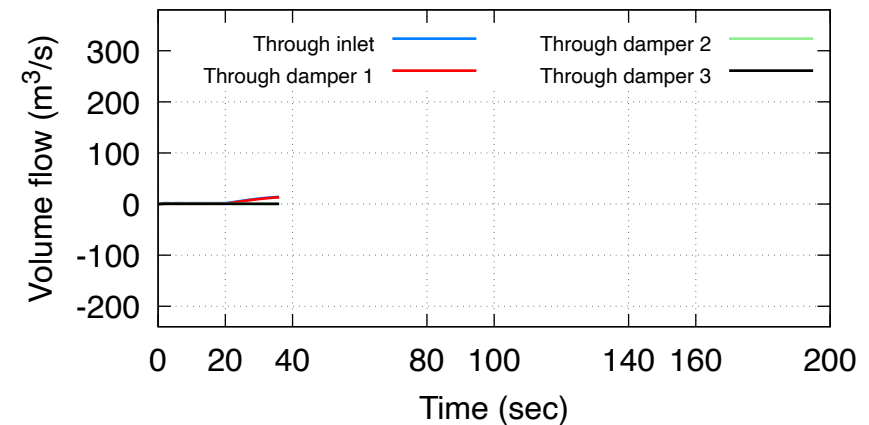
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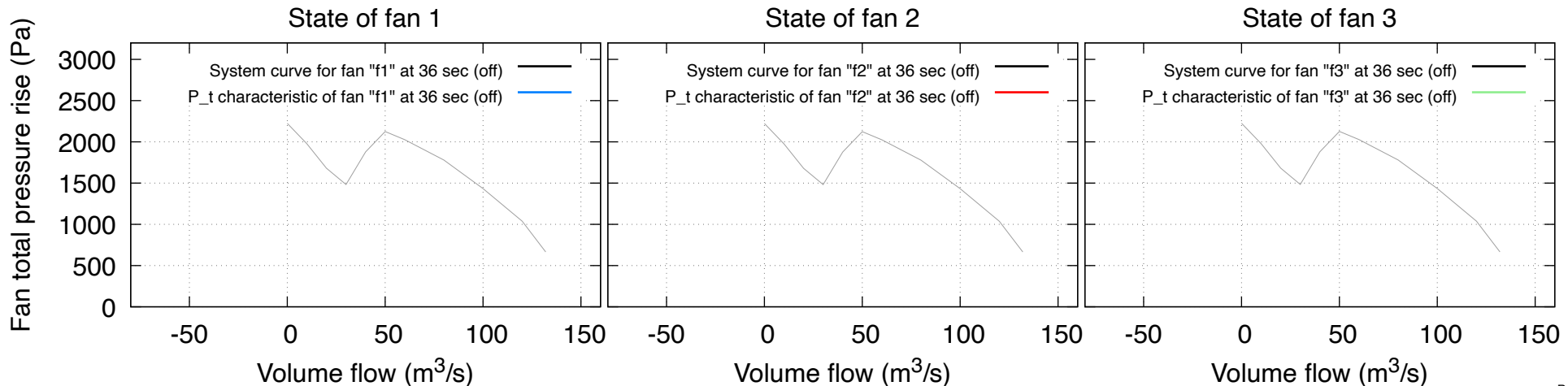
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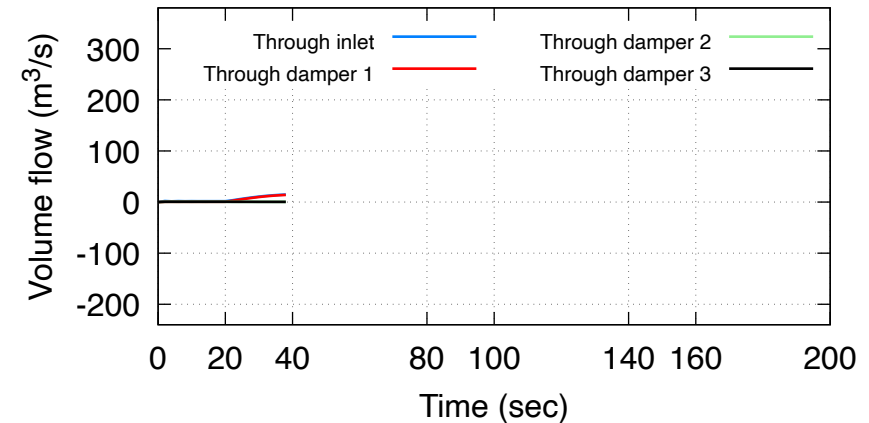
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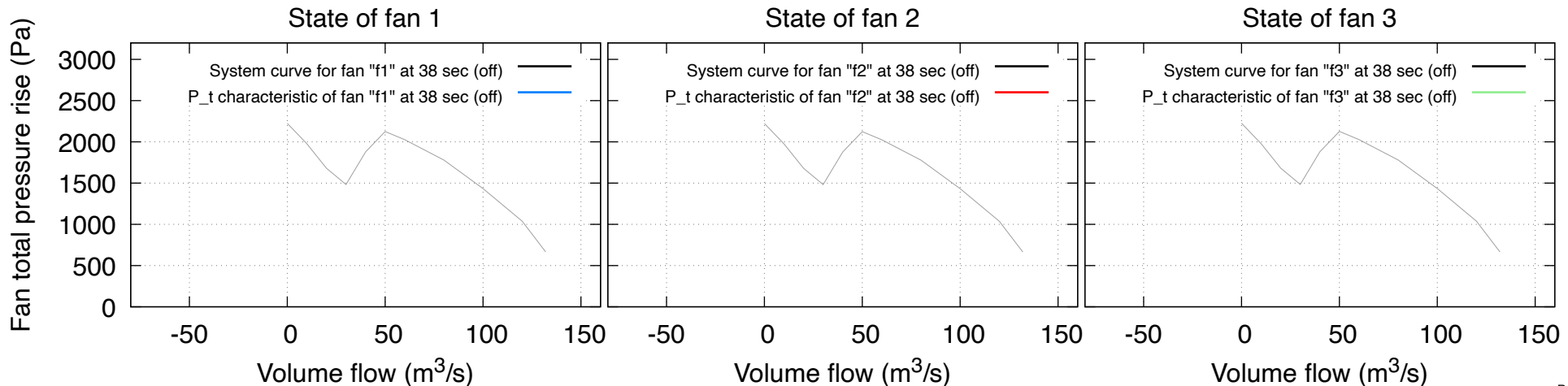
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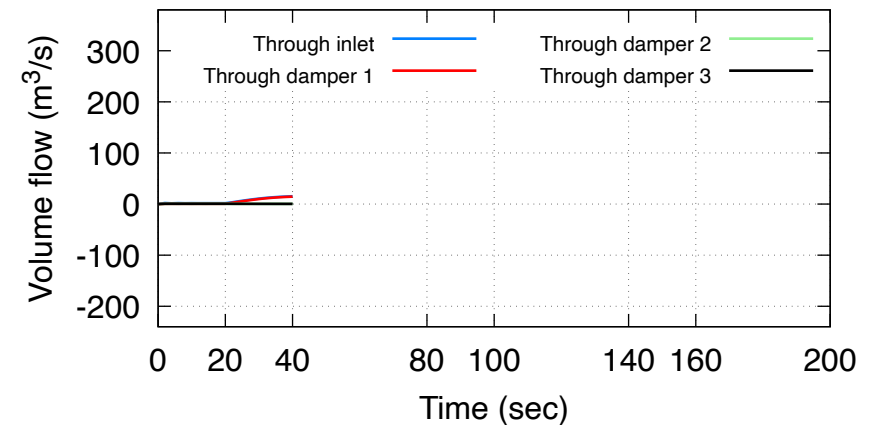
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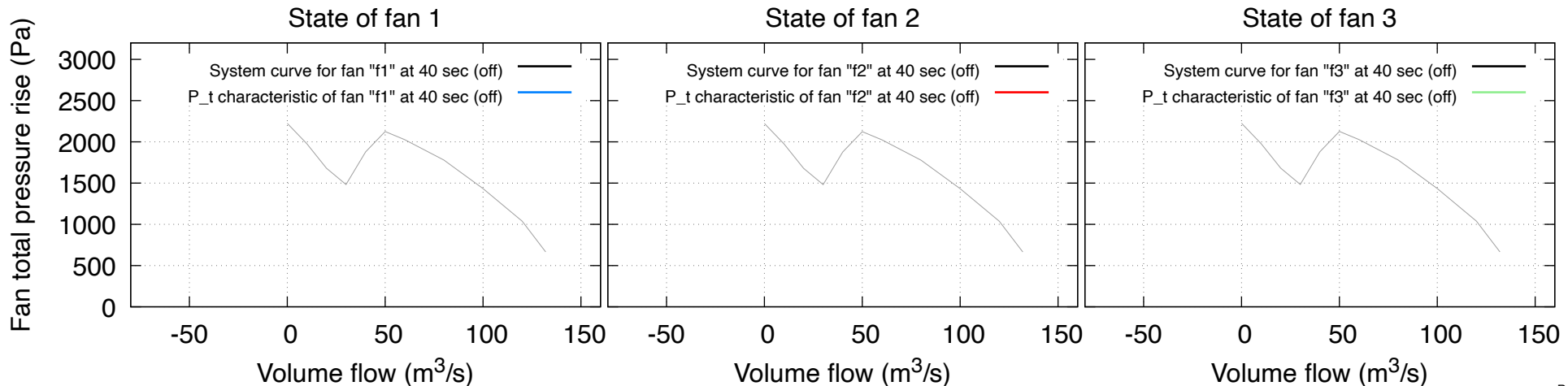
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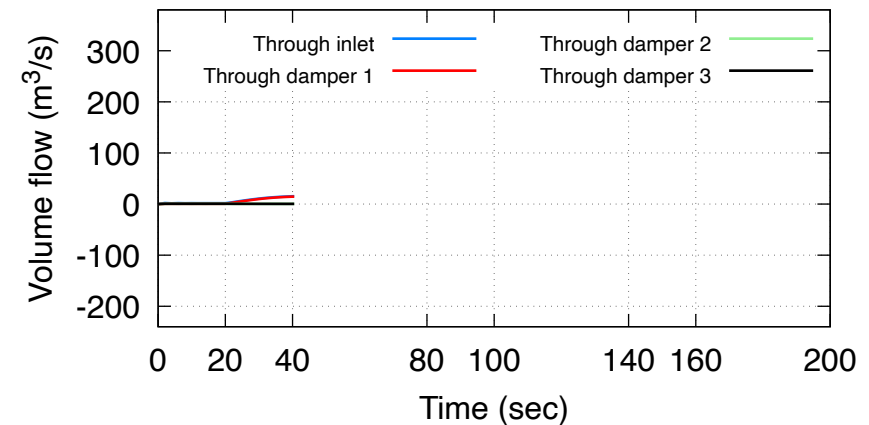
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The fans are started sequentially. Fans 1 and 2 get to suitable parts of their characteristics. Fan 3 can't get out of stall.



Transient volume flows in the system



At 20 seconds, damper 1 opens

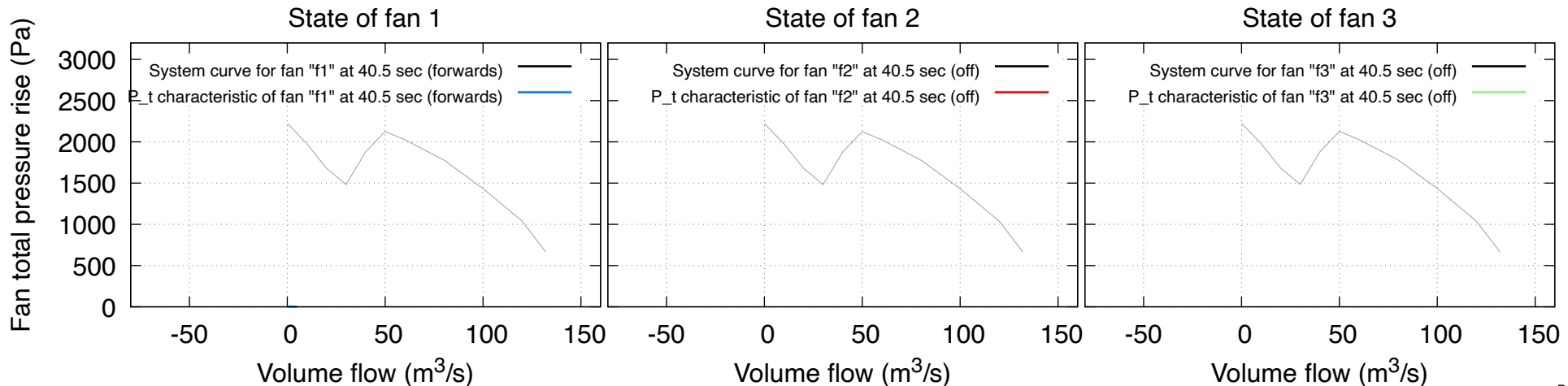
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

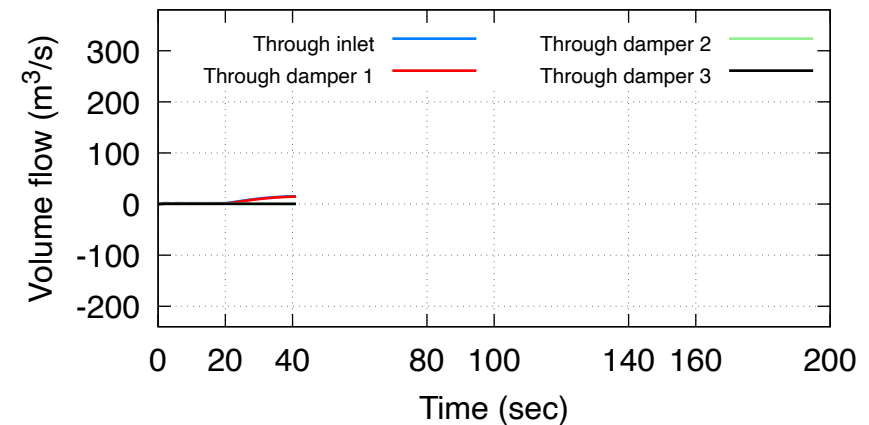
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

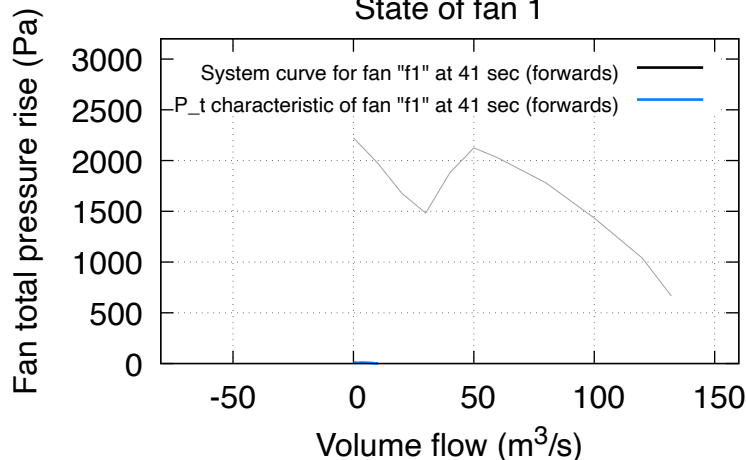
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

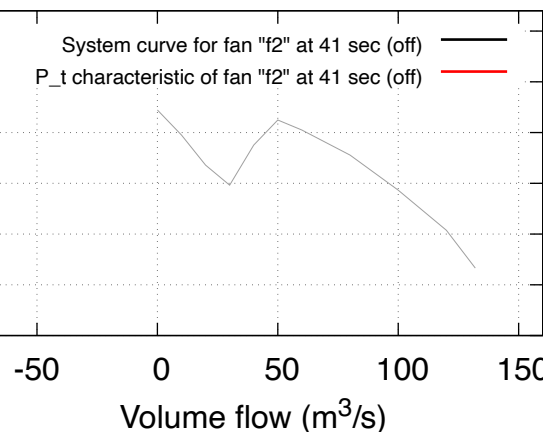
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

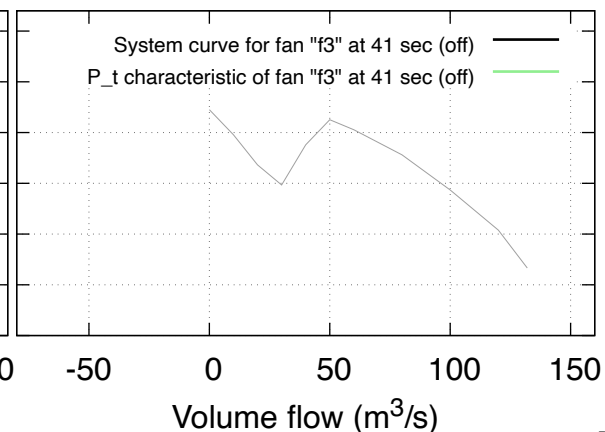
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

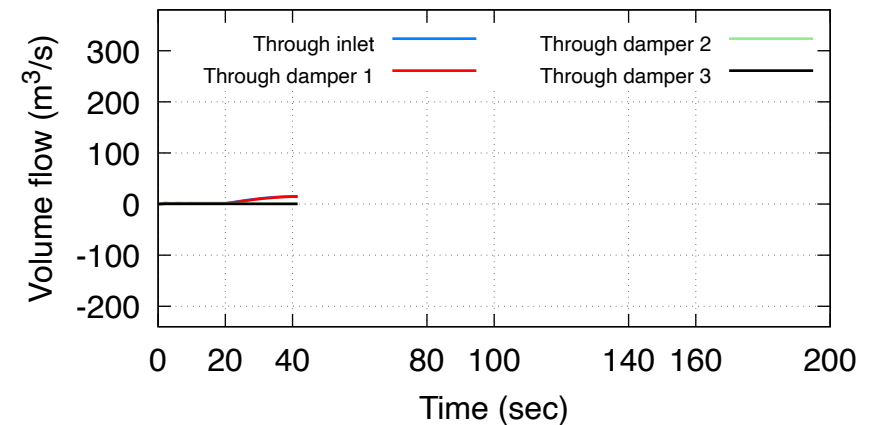
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

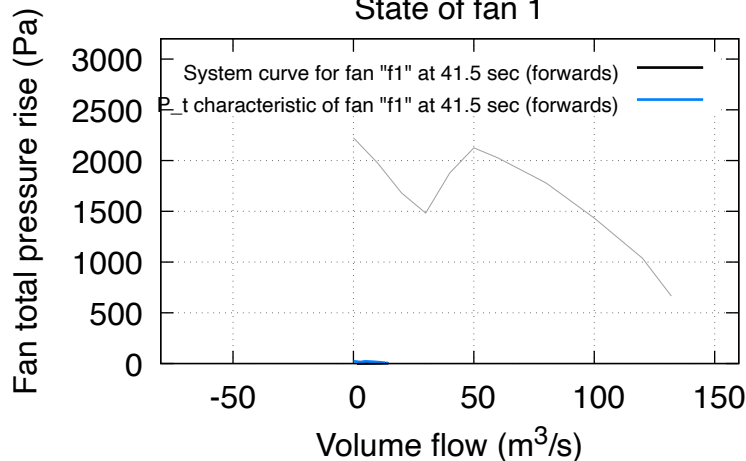
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

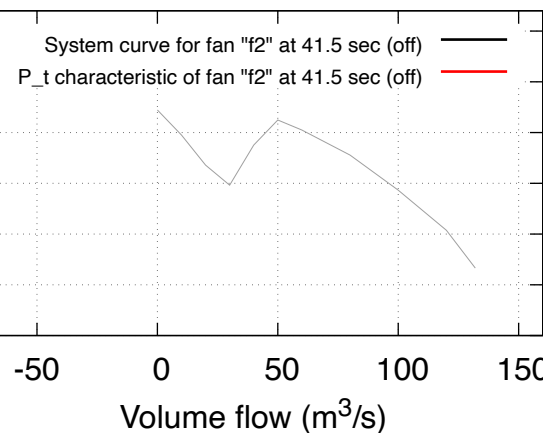
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

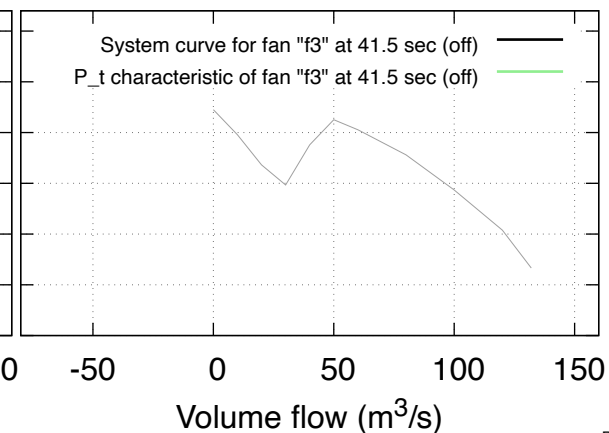
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

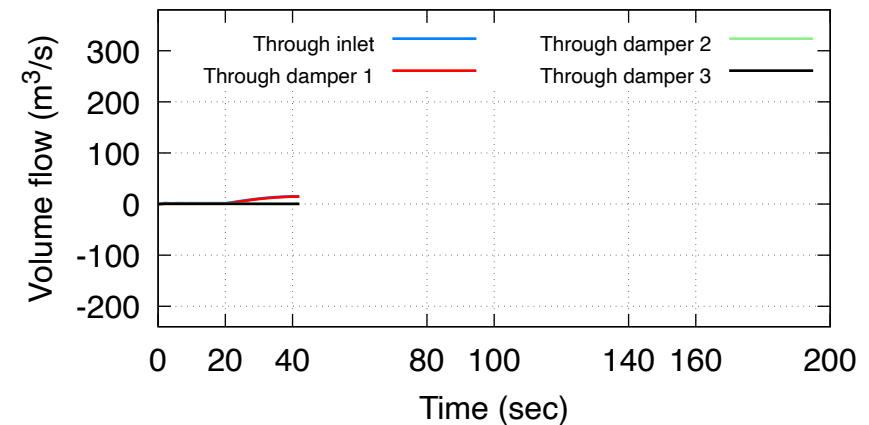
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

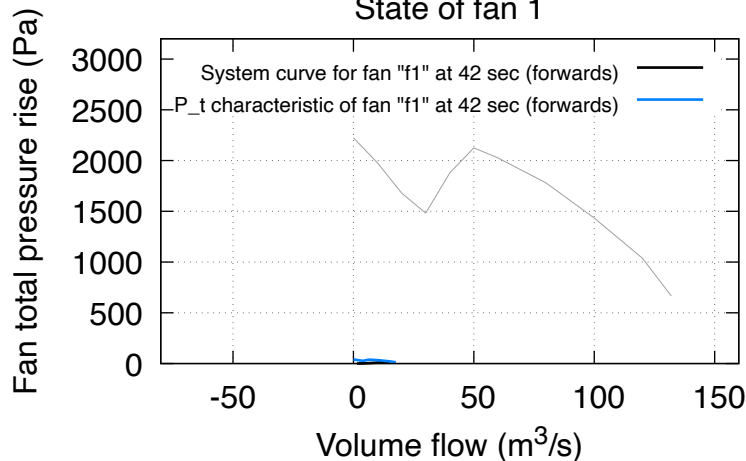
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

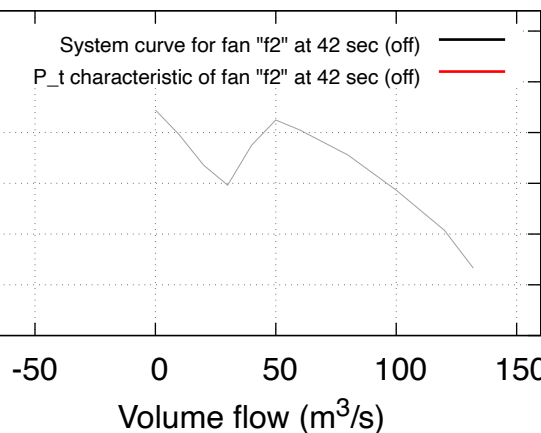
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

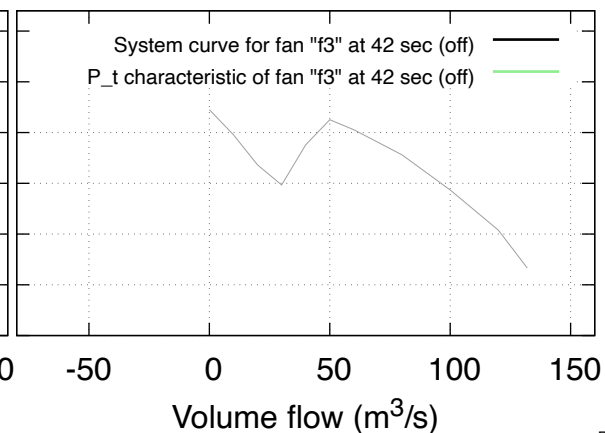
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

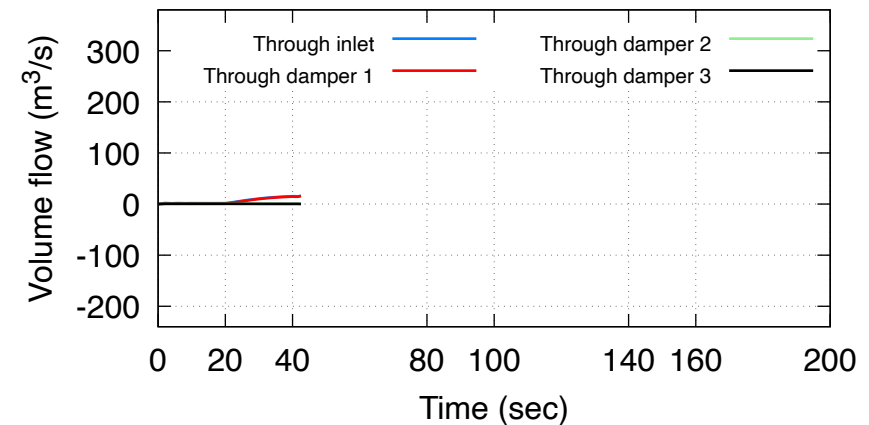
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Transient volume flows in the system



At 20 seconds, damper 1 opens

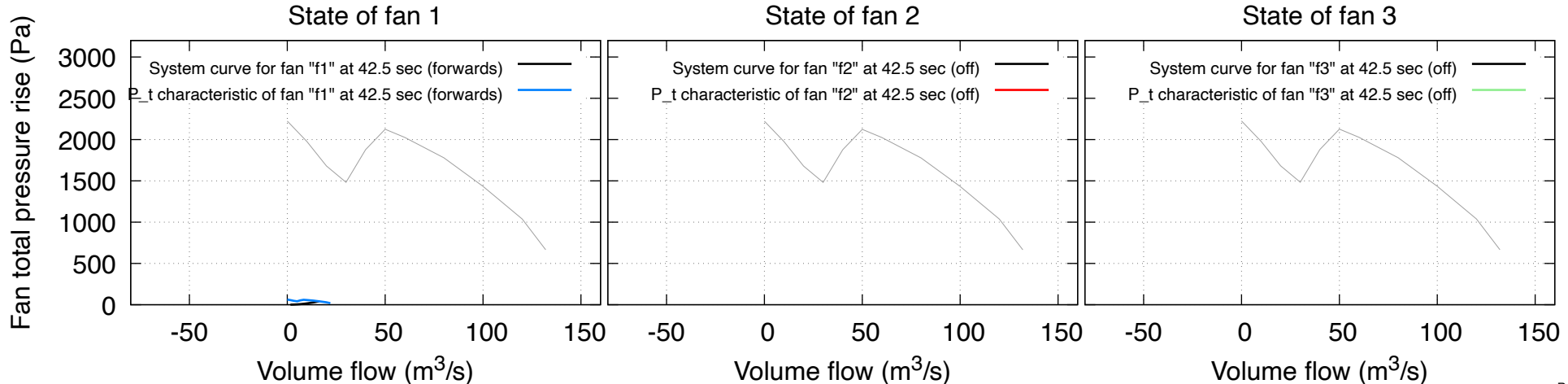
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

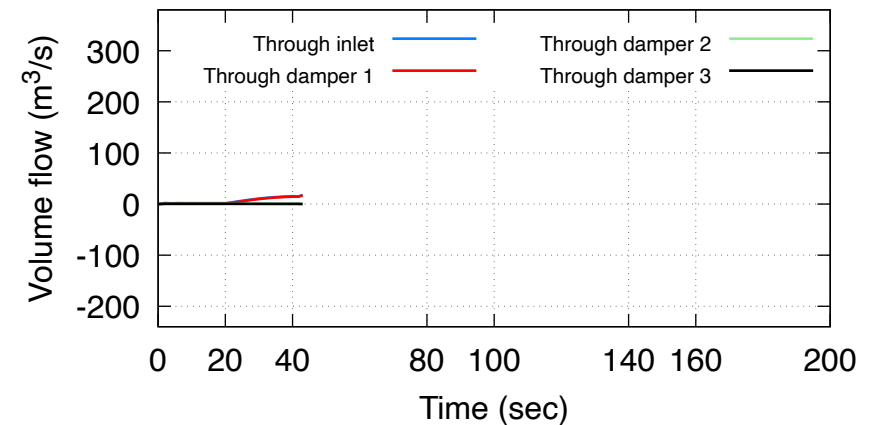
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Transient volume flows in the system



At 20 seconds, damper 1 opens

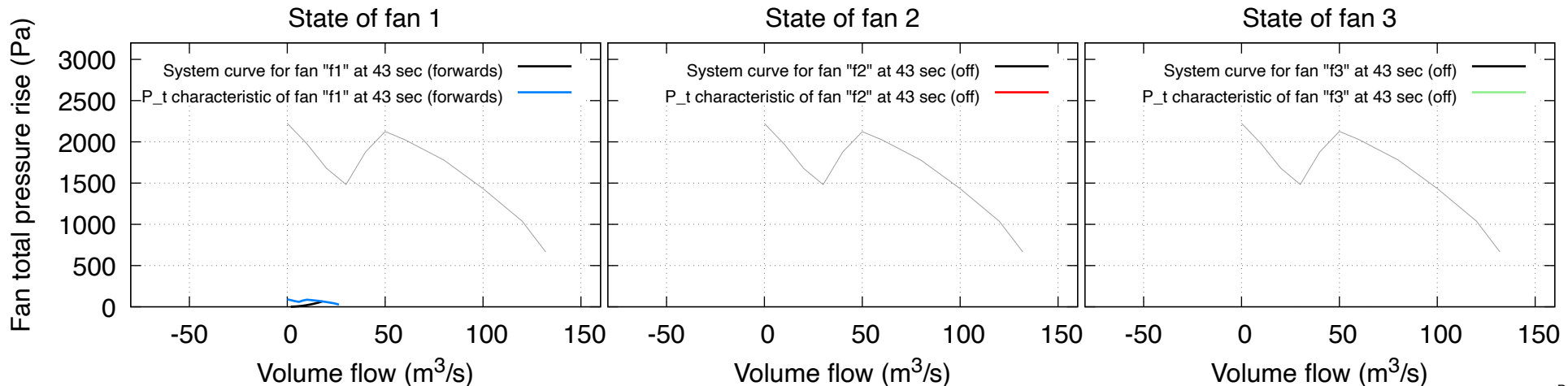
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

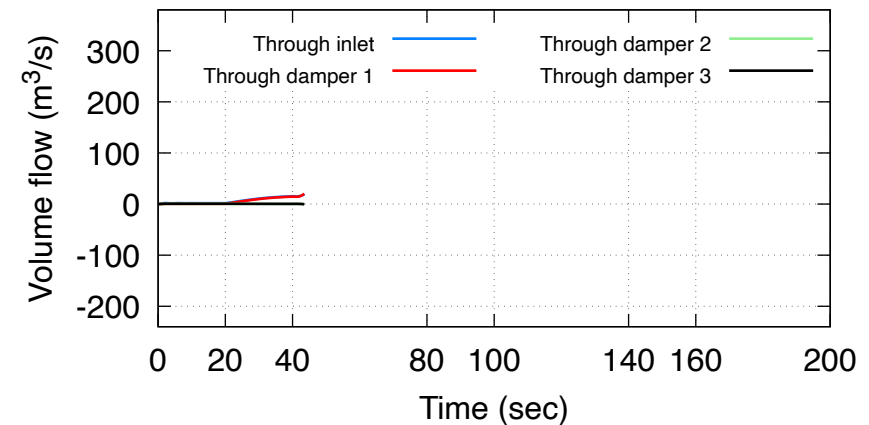
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Transient volume flows in the system



At 20 seconds, damper 1 opens

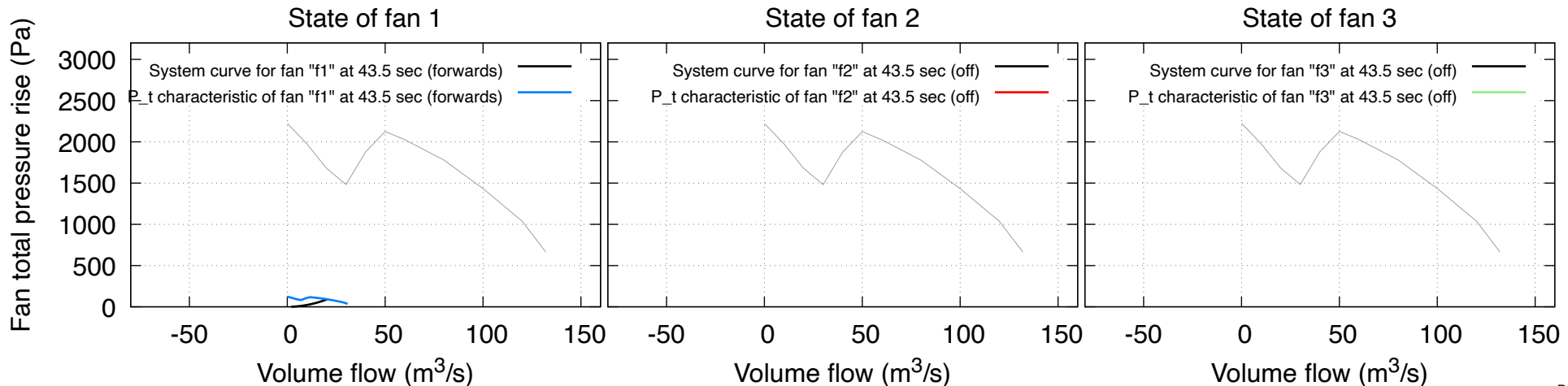
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

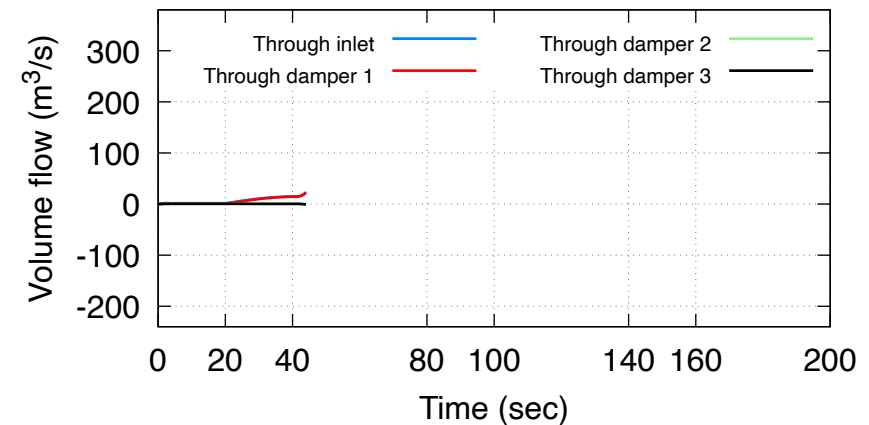
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

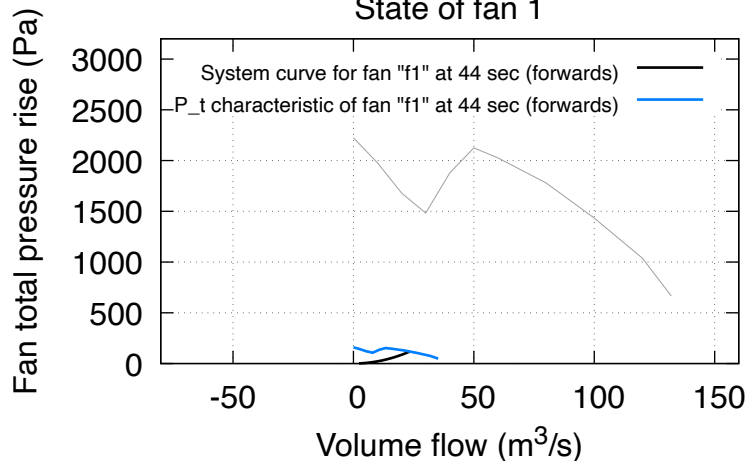
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

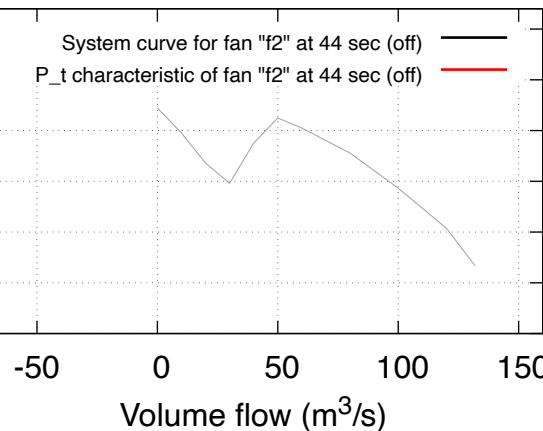
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

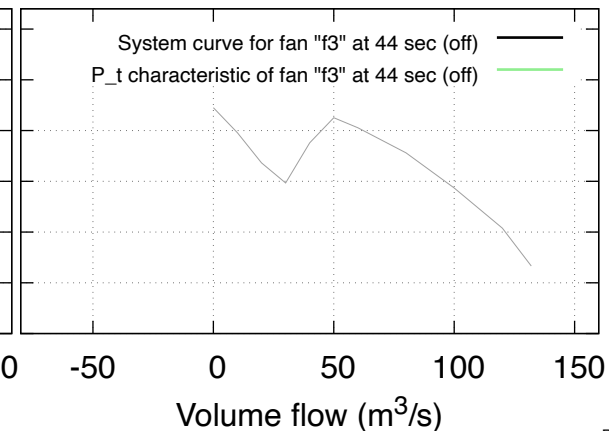
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

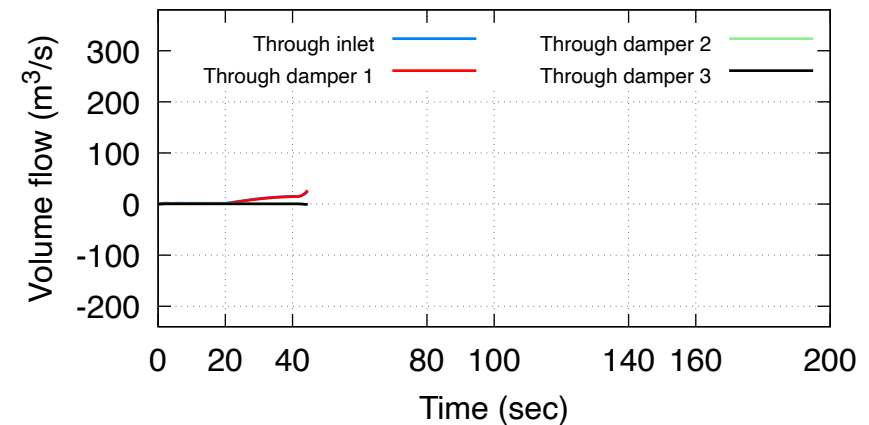
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Transient volume flows in the system



At 20 seconds, damper 1 opens

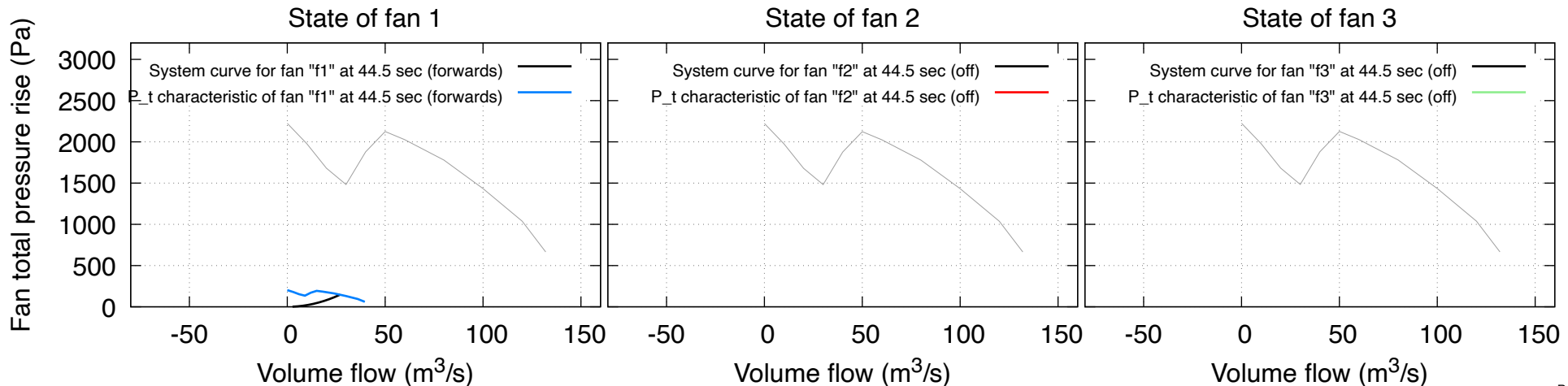
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

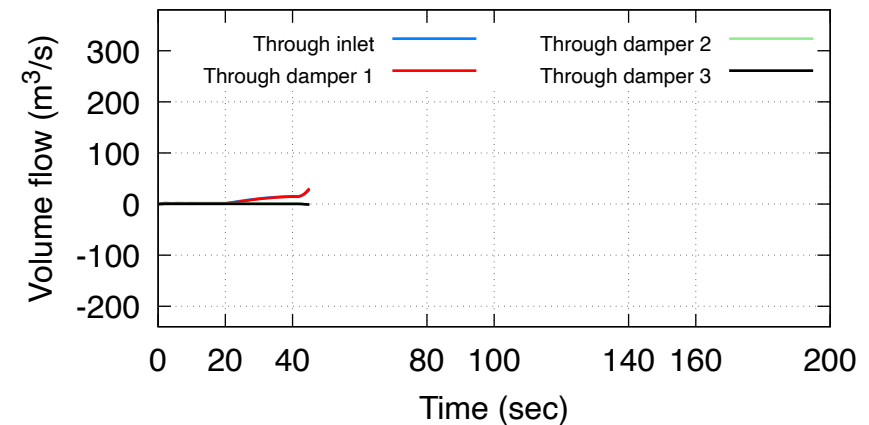
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Transient volume flows in the system



At 20 seconds, damper 1 opens

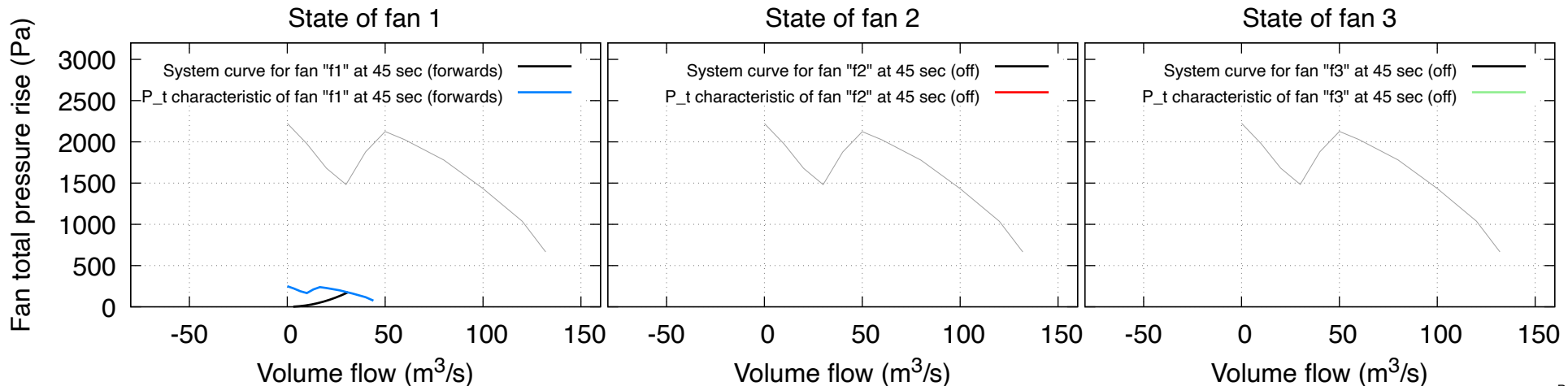
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

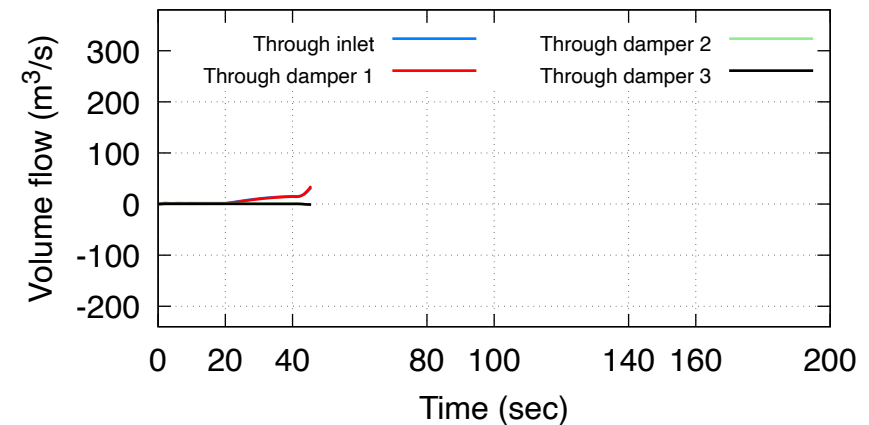
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At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

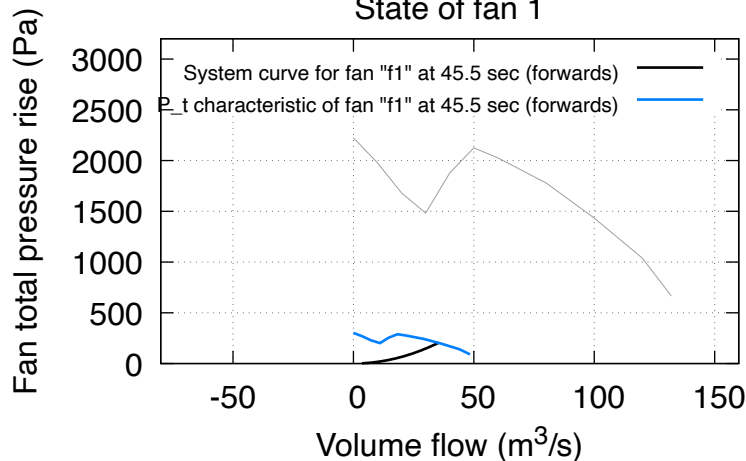
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

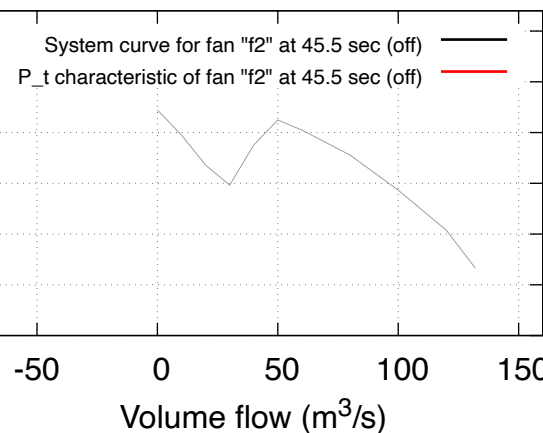
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

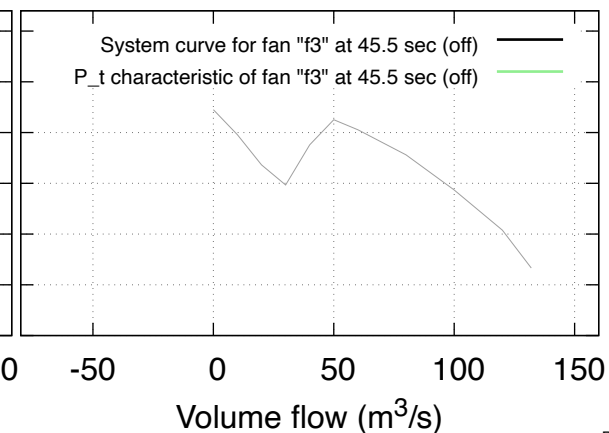
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

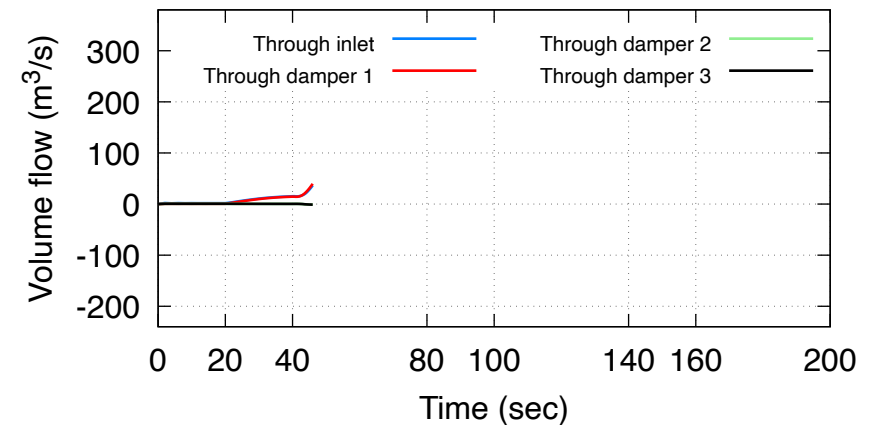
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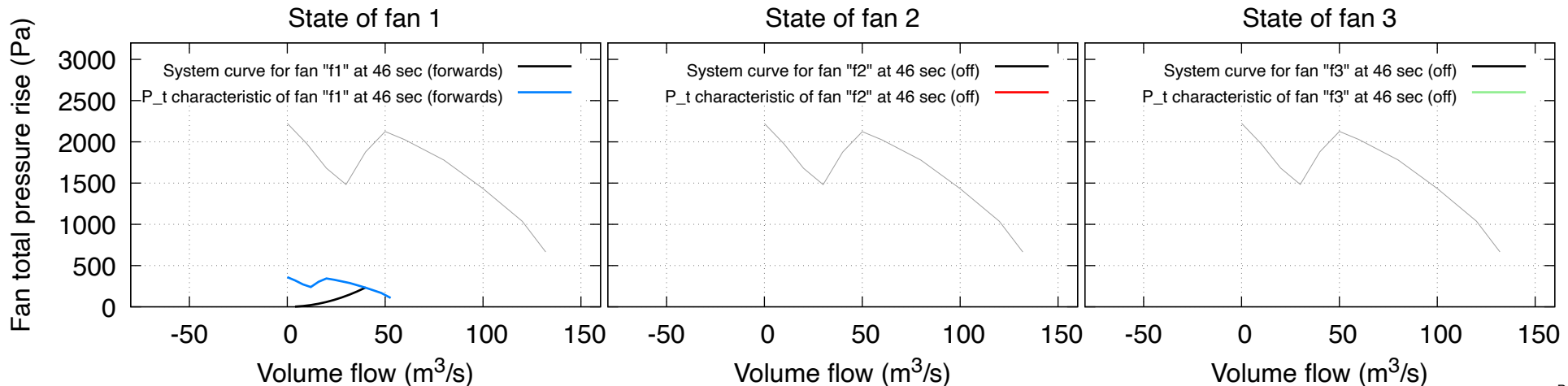
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

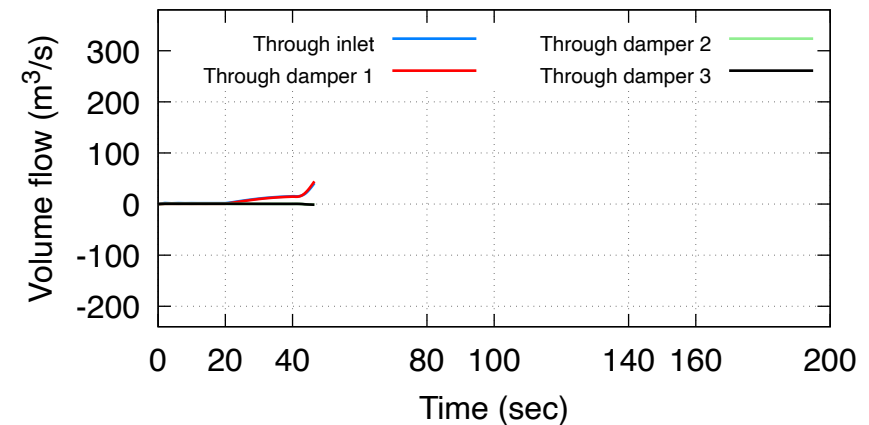
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Transient volume flows in the system



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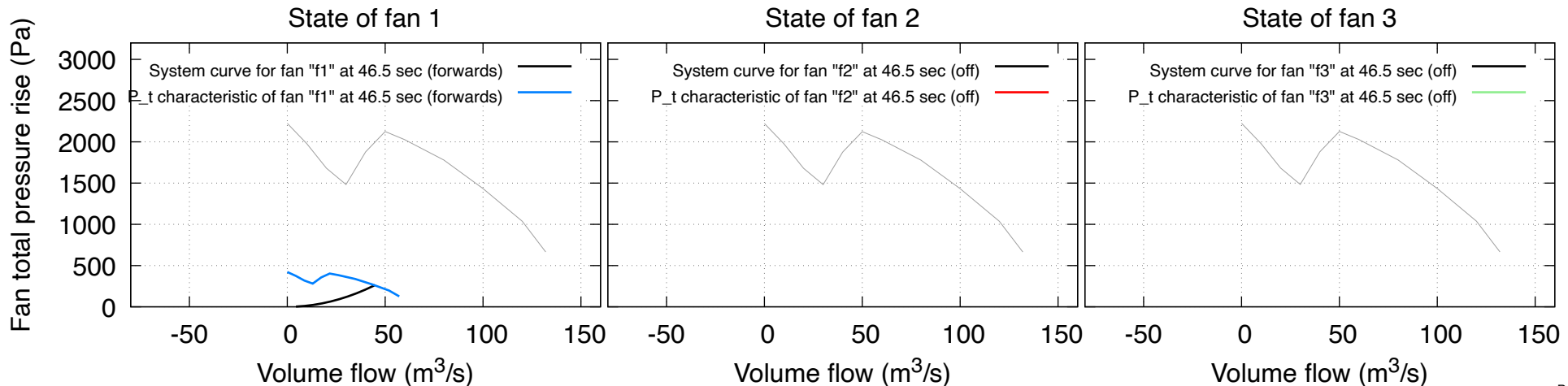
At 40 seconds, fan 1 starts

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At 160 seconds, fan 3 starts



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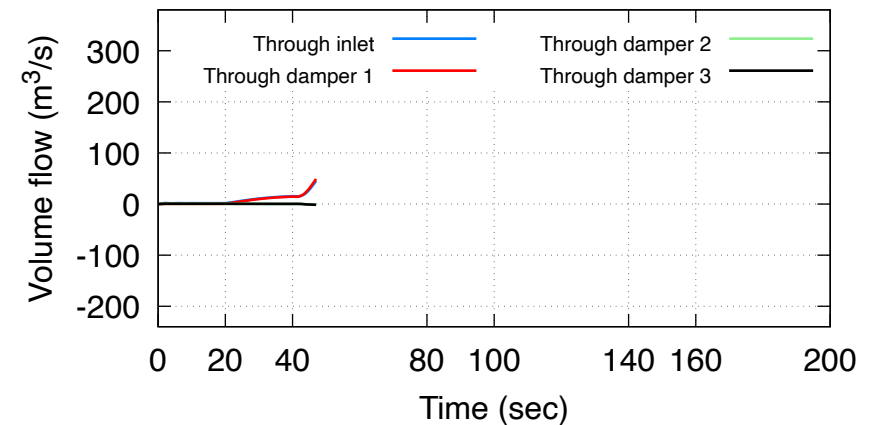
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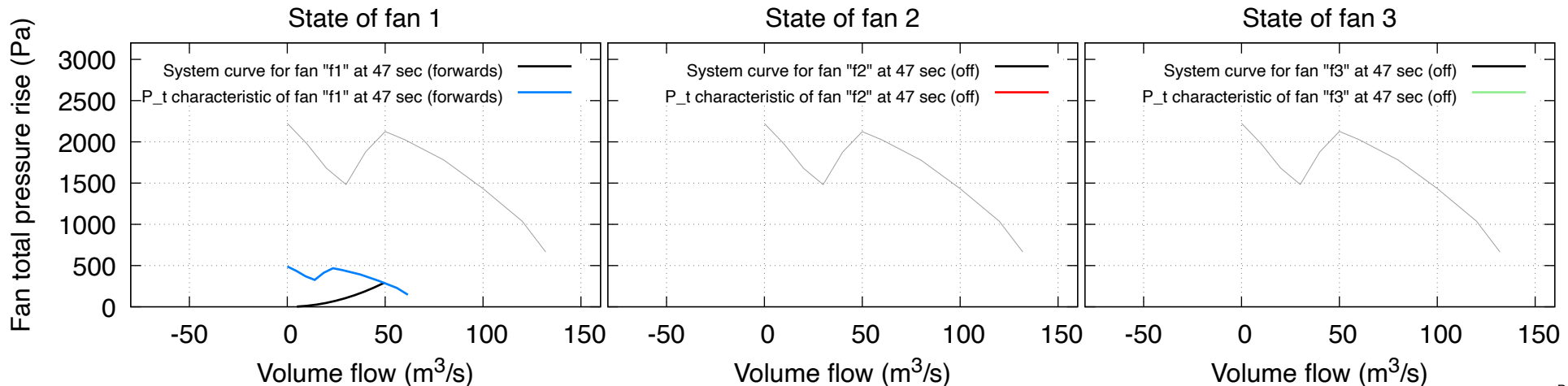
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At 160 seconds, fan 3 starts



How not to run fans in parallel

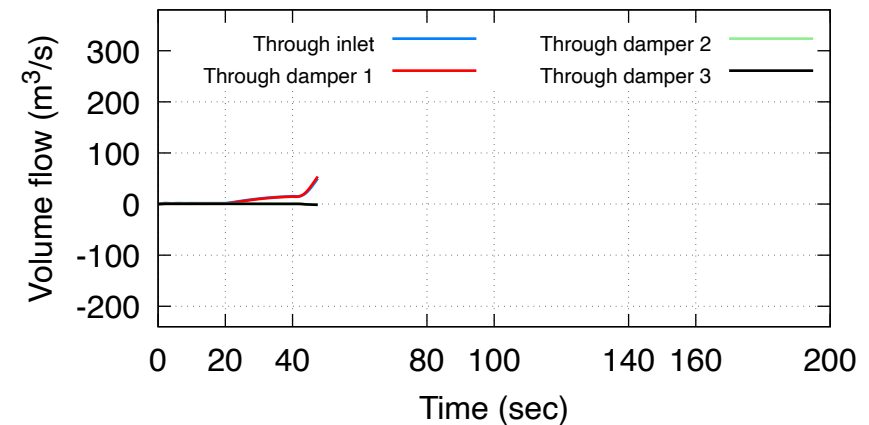
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Transient volume flows in the system



At 20 seconds, damper 1 opens

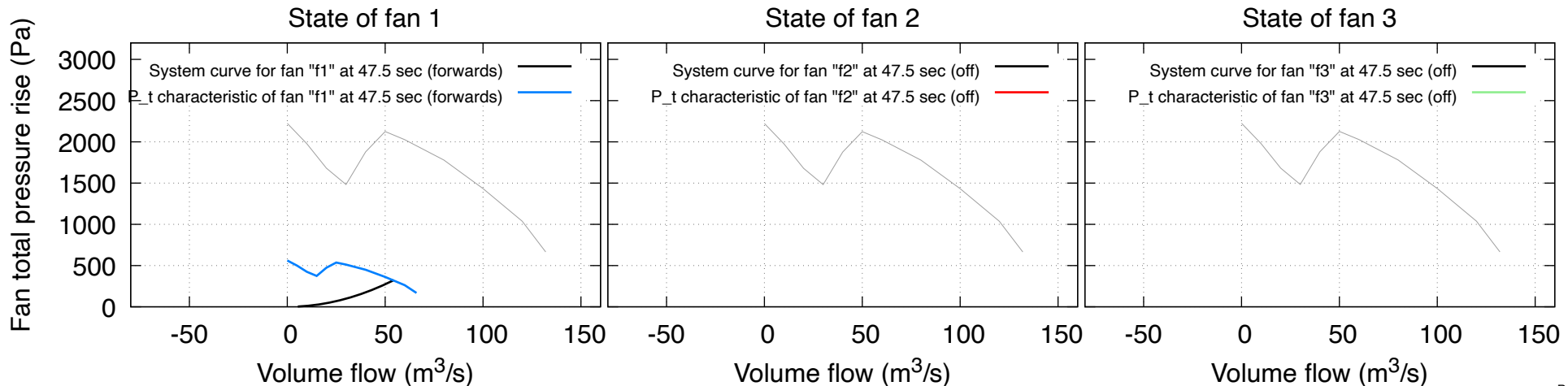
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

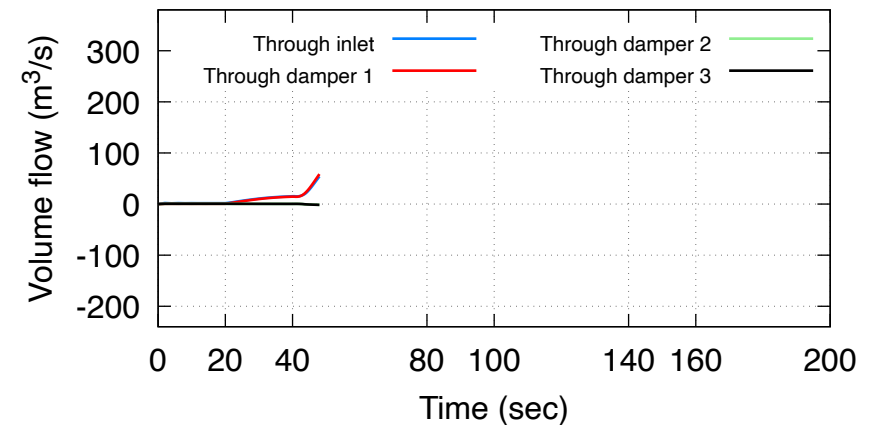
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At 20 seconds, damper 1 opens

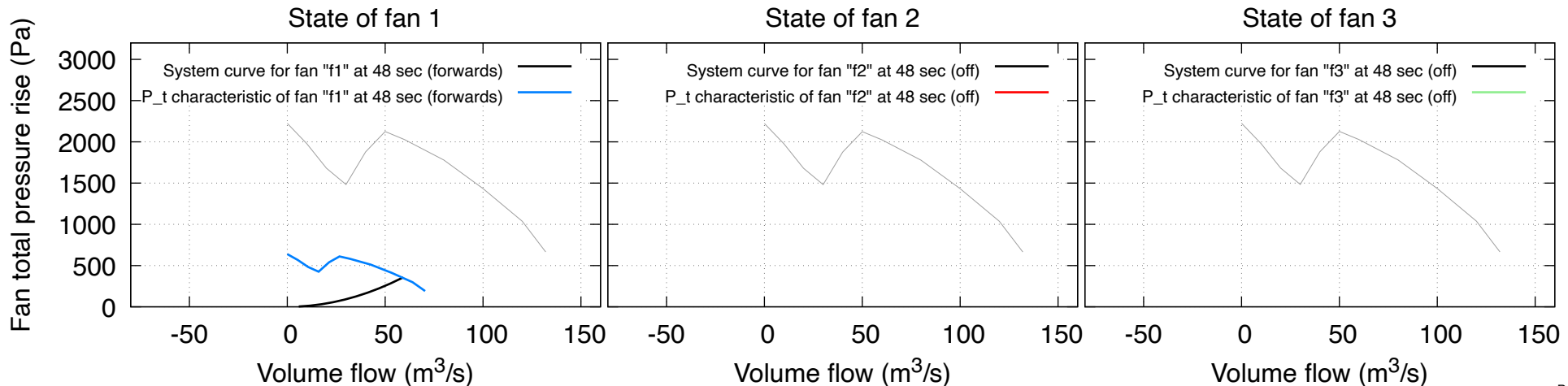
At 40 seconds, fan 1 starts

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How not to run fans in parallel

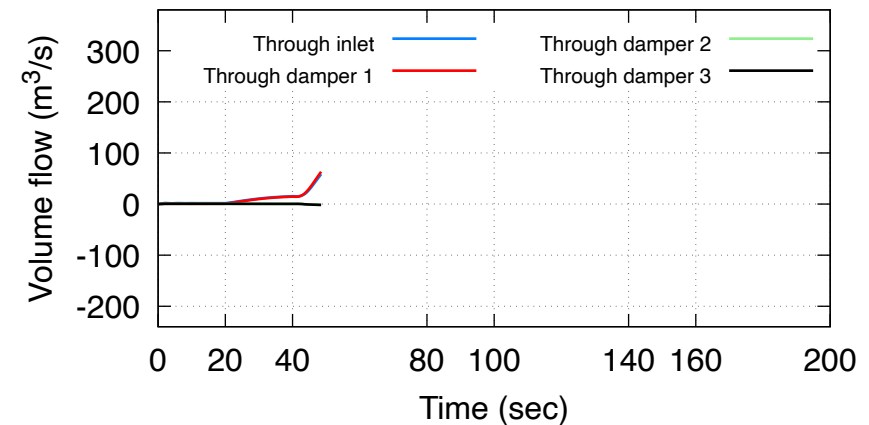
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At 20 seconds, damper 1 opens

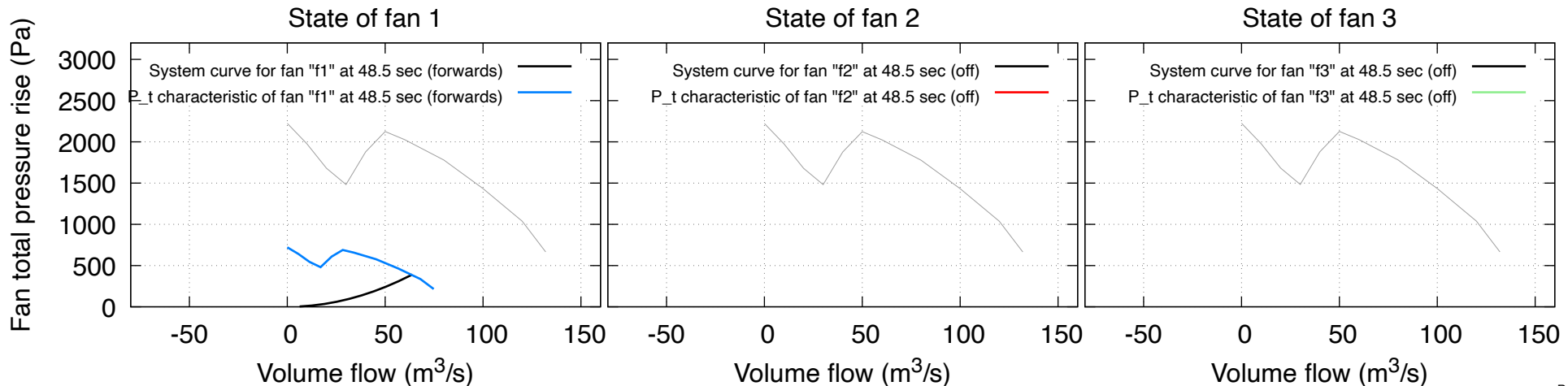
At 40 seconds, fan 1 starts

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How not to run fans in parallel

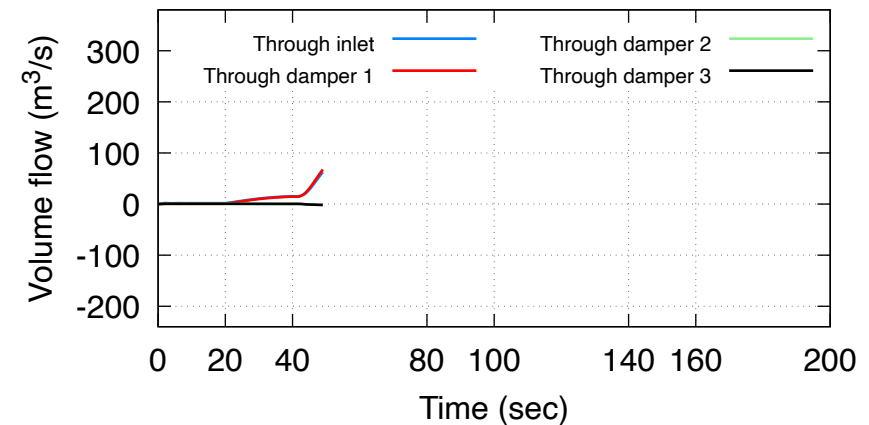
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

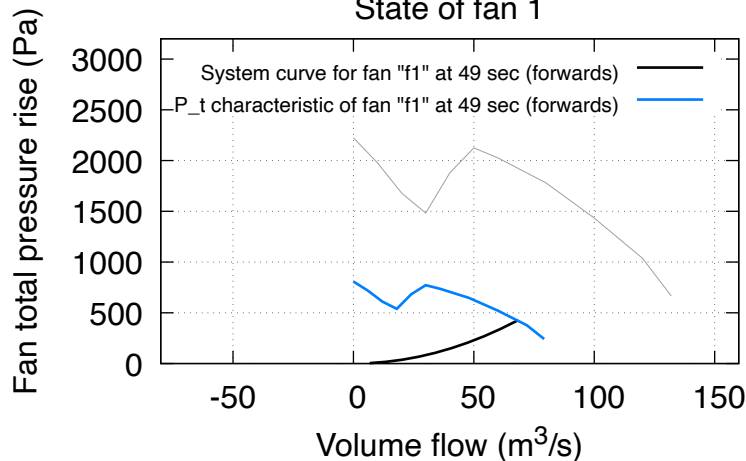
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

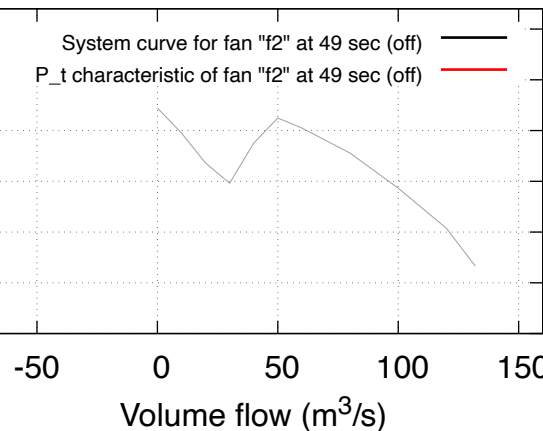
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

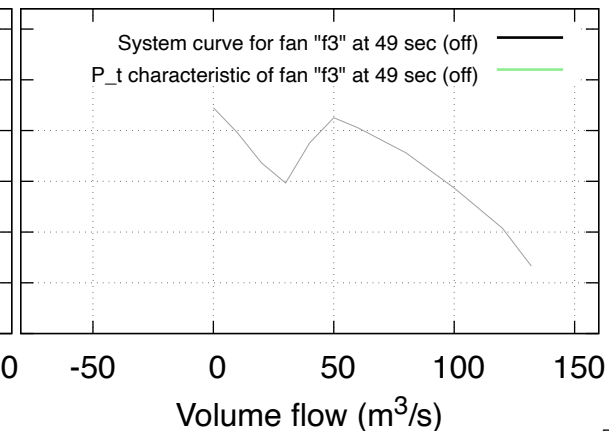
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

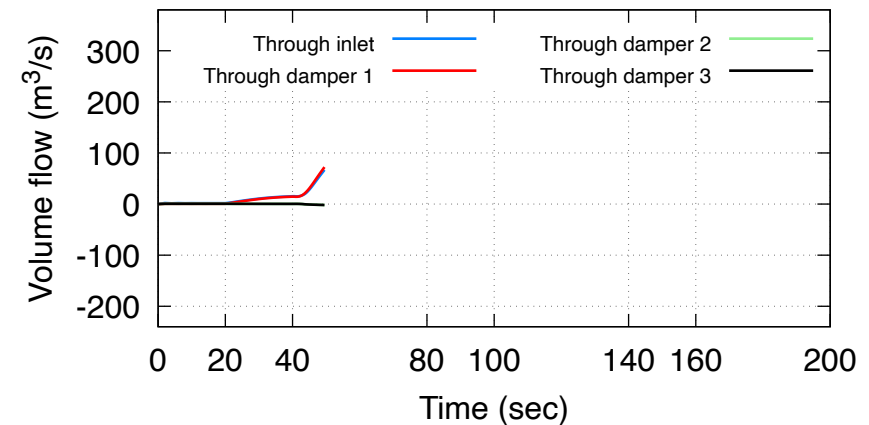
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At 20 seconds, damper 1 opens

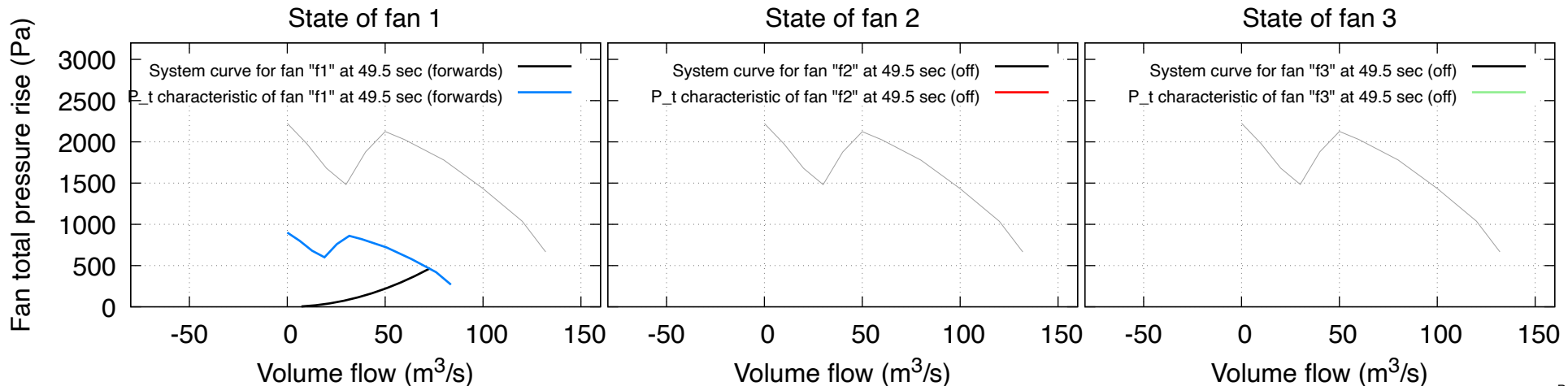
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



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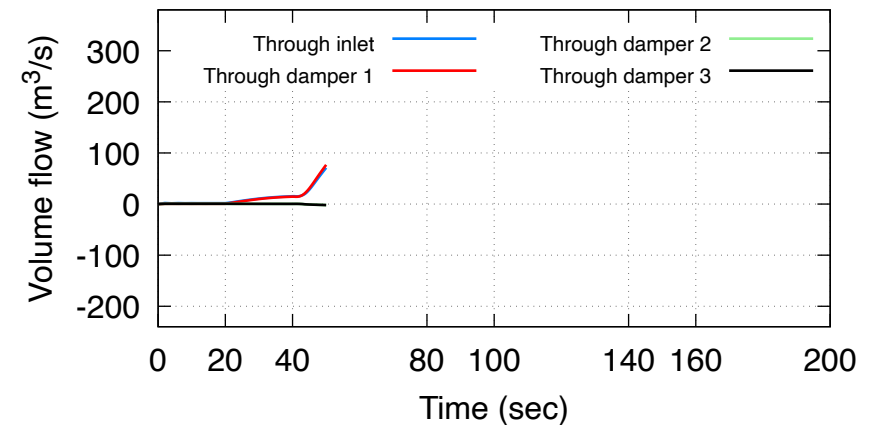
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At 20 seconds, damper 1 opens

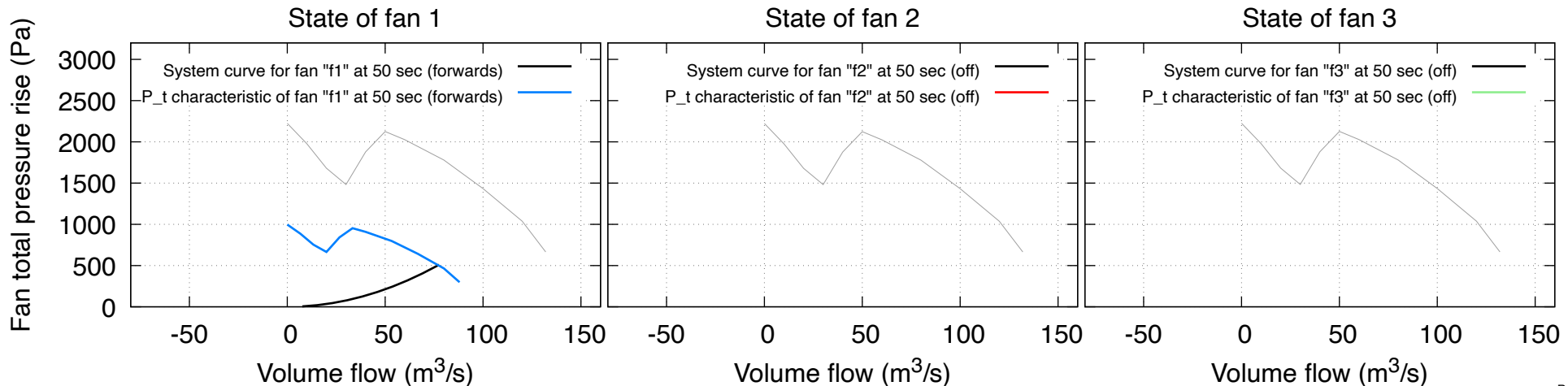
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

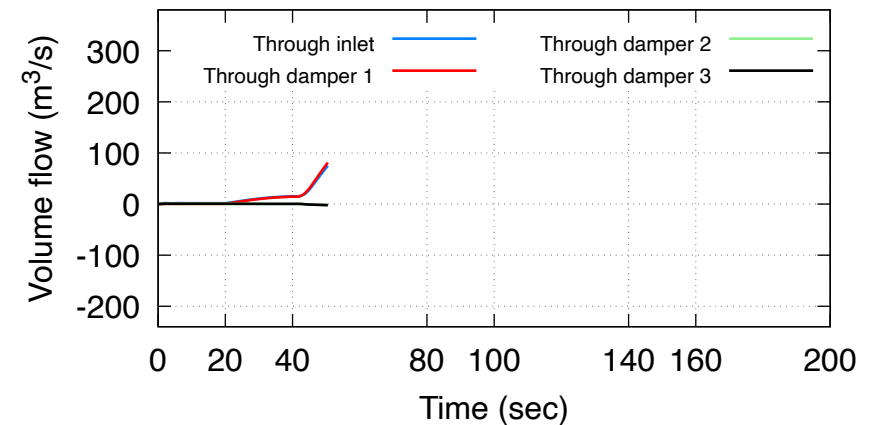
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At 20 seconds, damper 1 opens

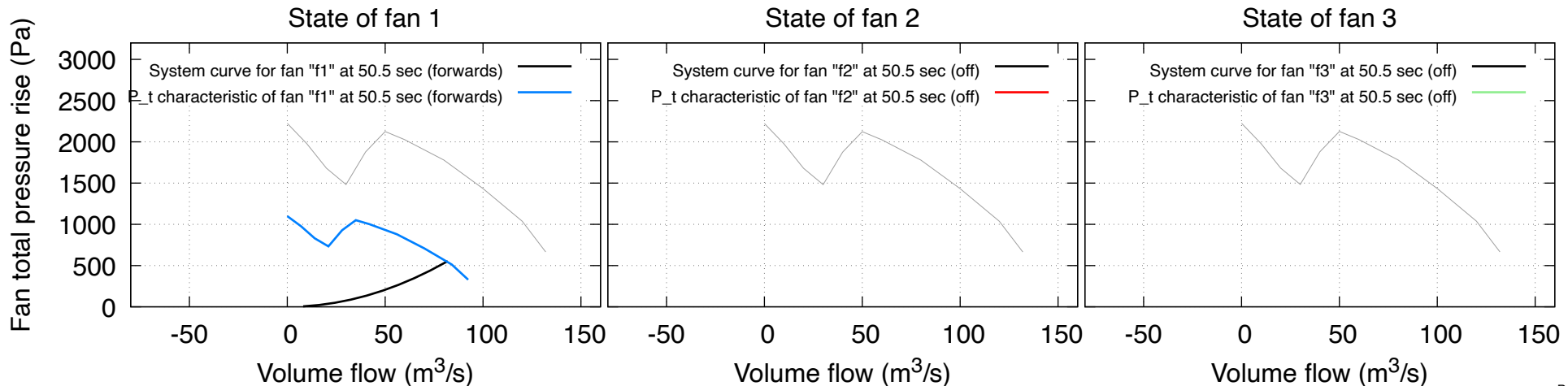
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How not to run fans in parallel

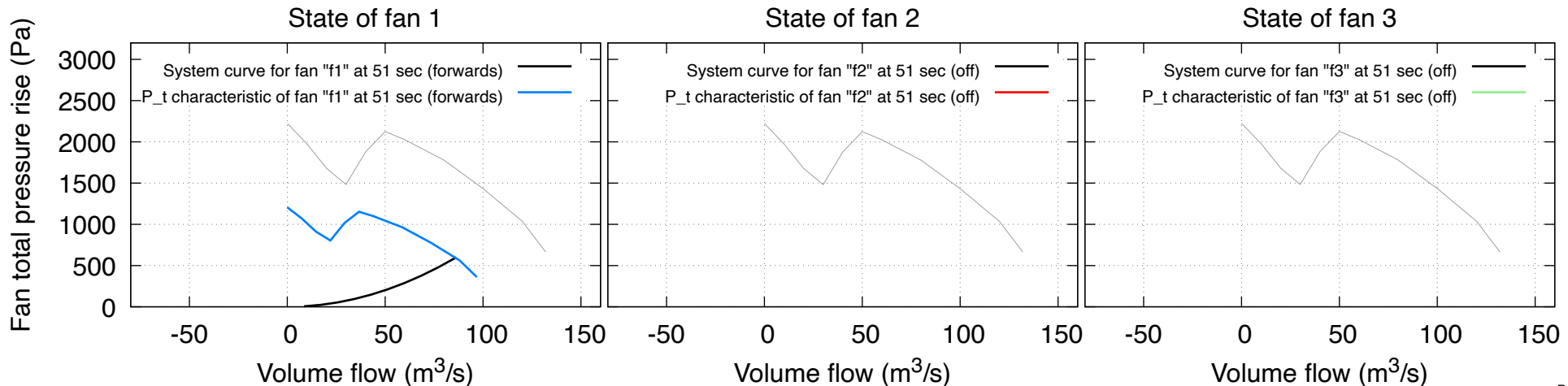
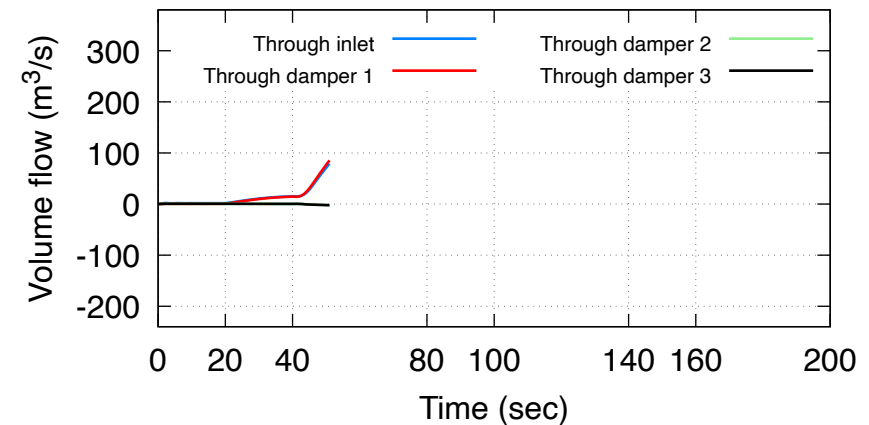
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Transient volume flows in the system



How not to run fans in parallel

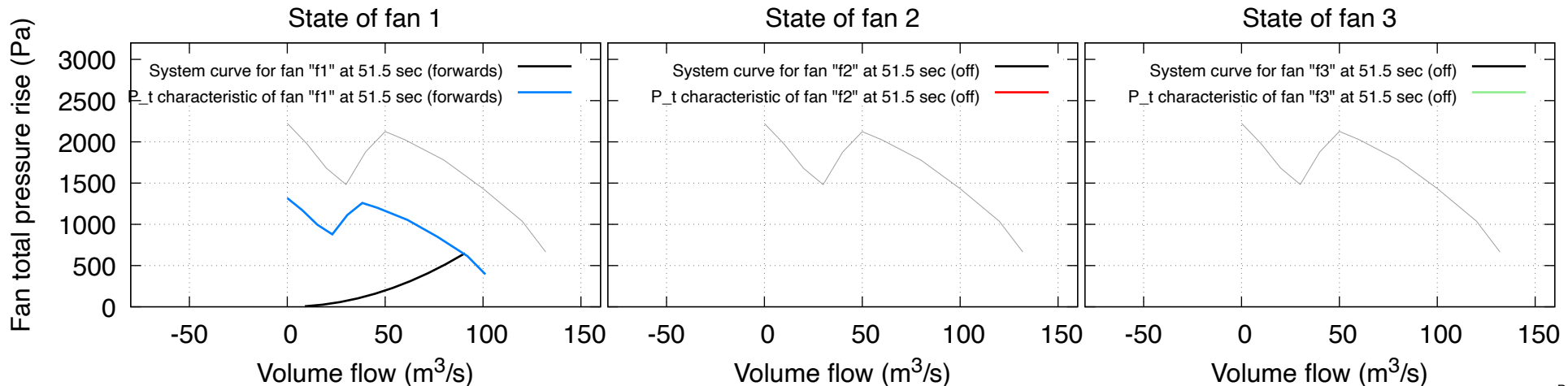
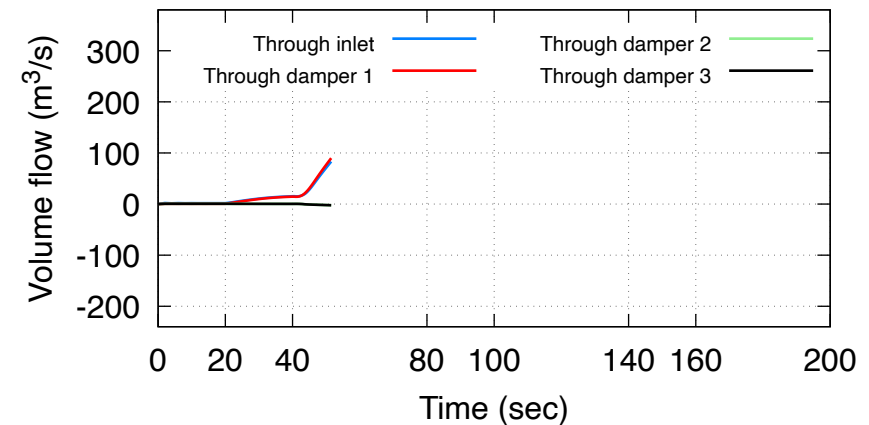
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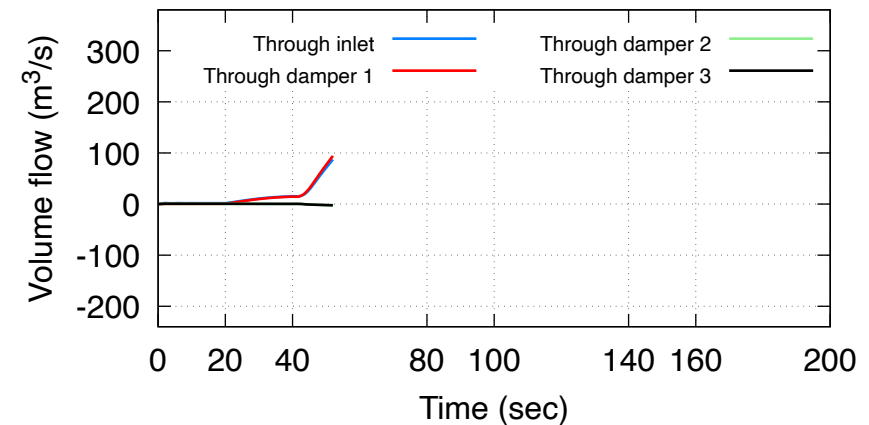
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

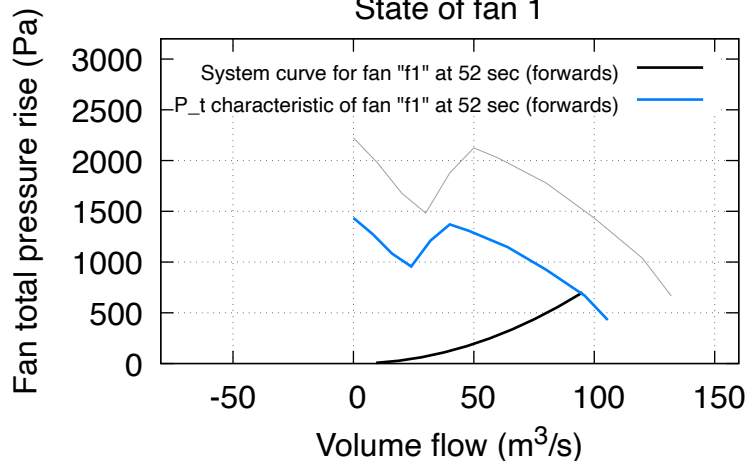
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

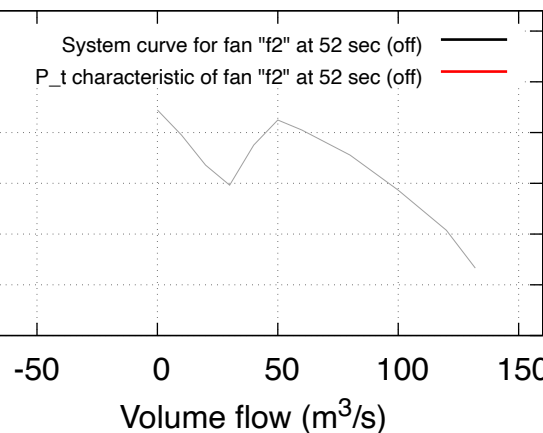
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

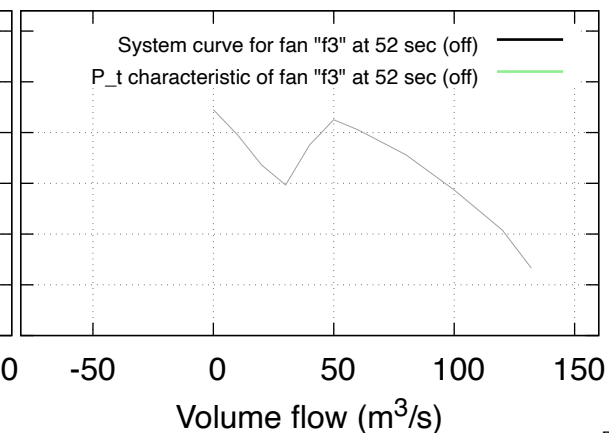
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

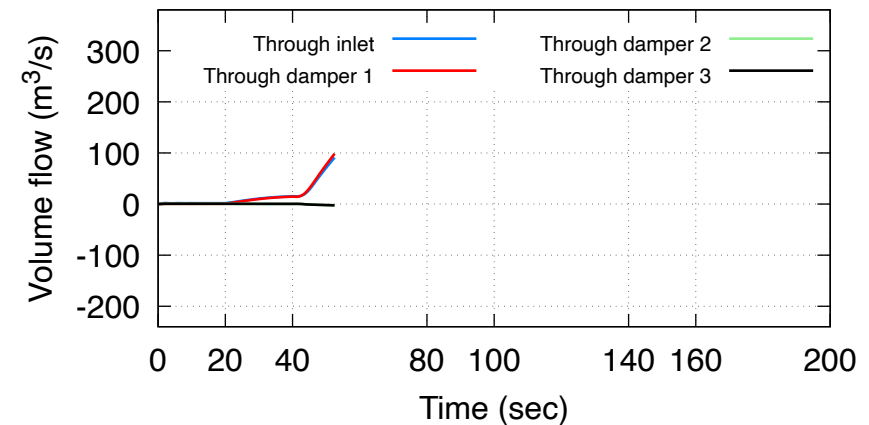
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Transient volume flows in the system



At 20 seconds, damper 1 opens

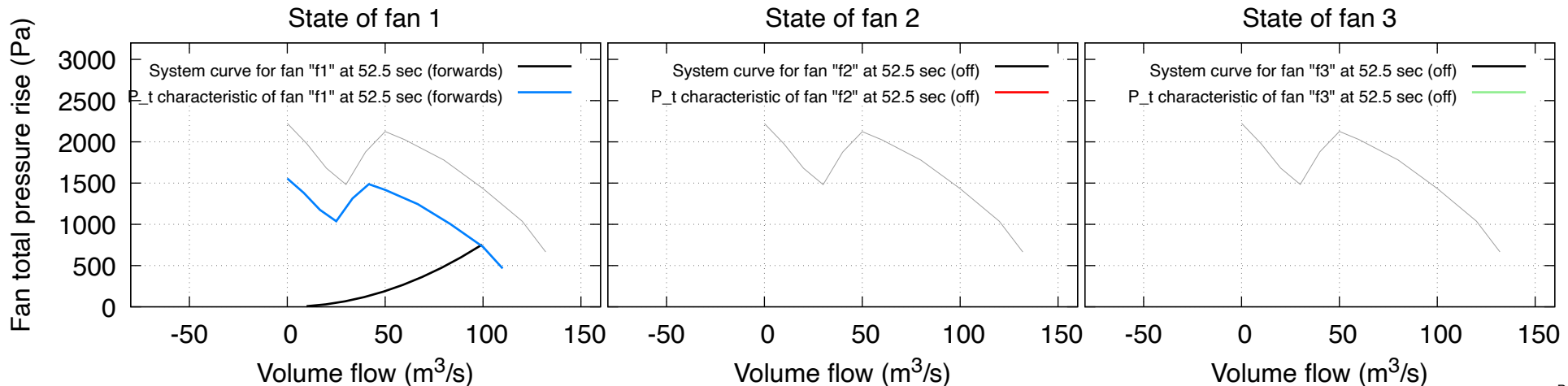
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At 100 seconds, fan 2 starts

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How not to run fans in parallel

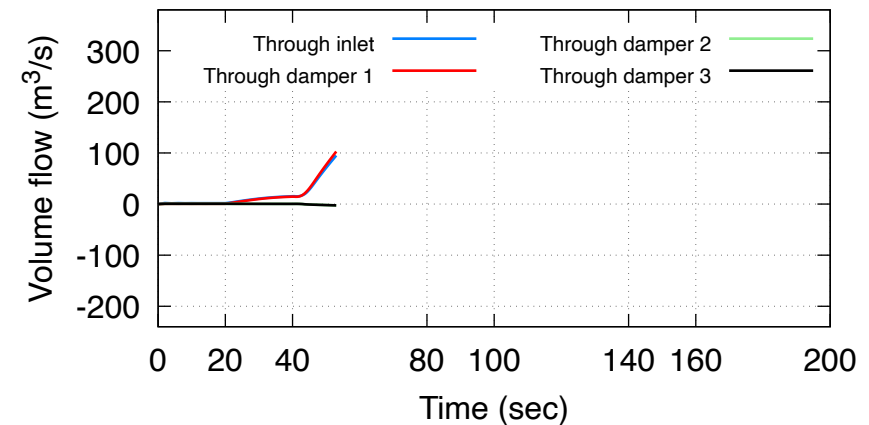
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Transient volume flows in the system



At 20 seconds, damper 1 opens

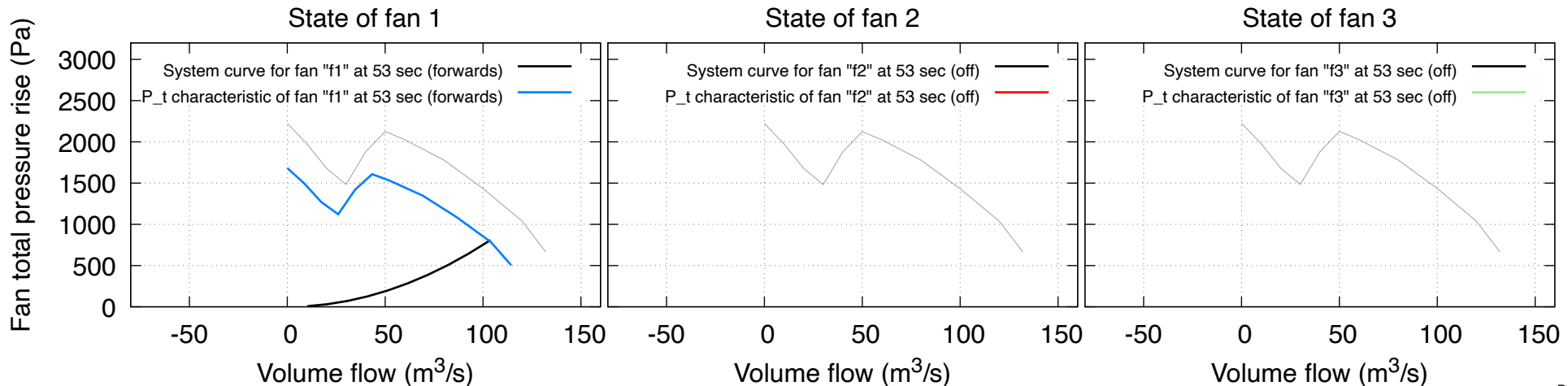
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How not to run fans in parallel

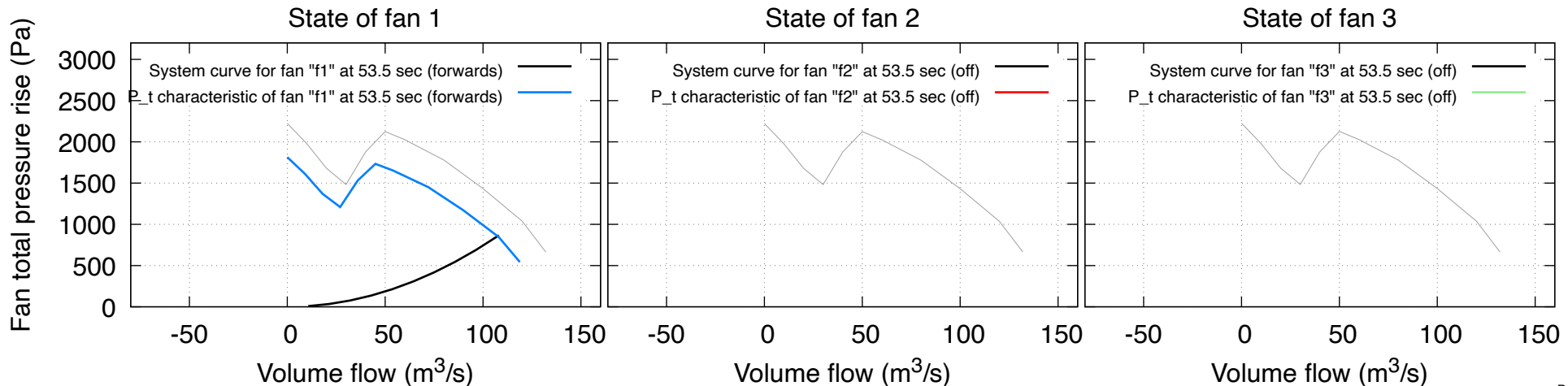
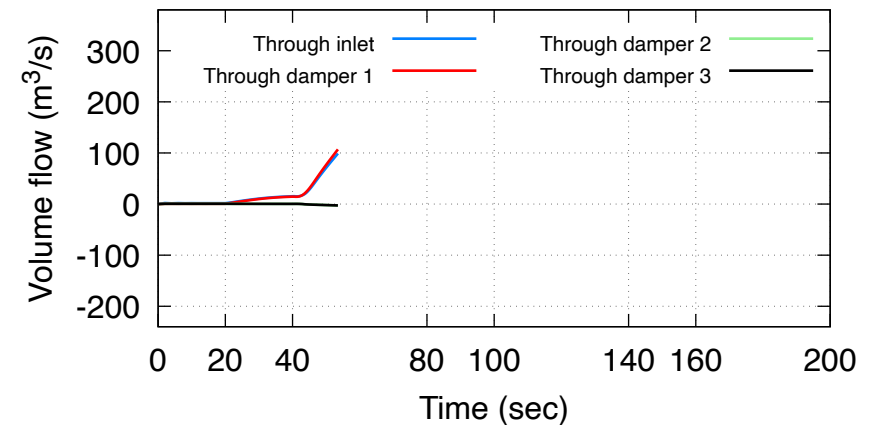
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Transient volume flows in the system



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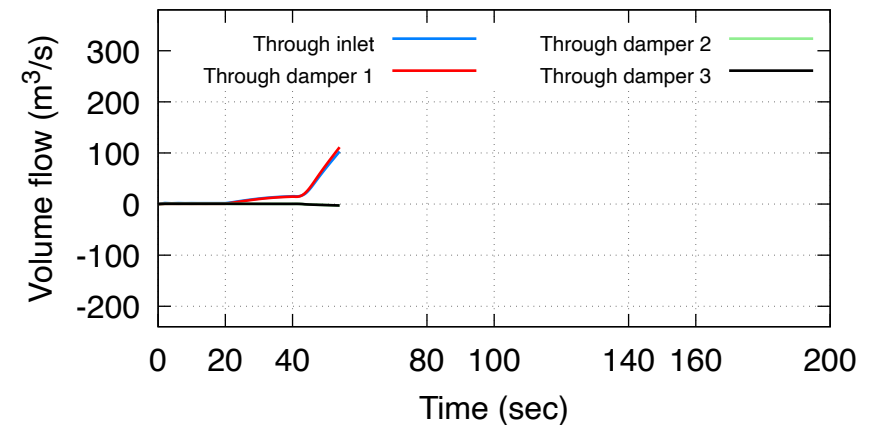
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Transient volume flows in the system



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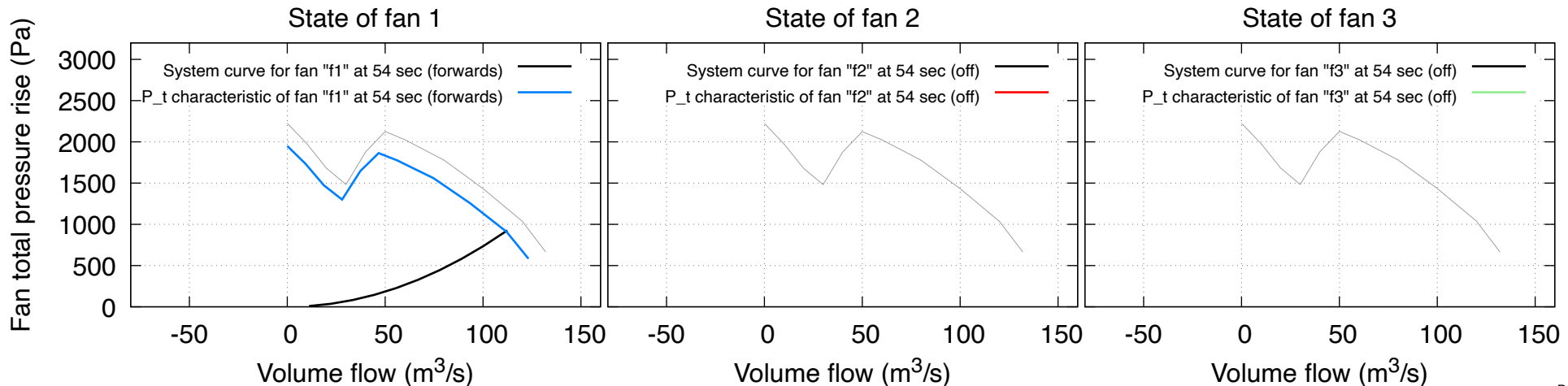
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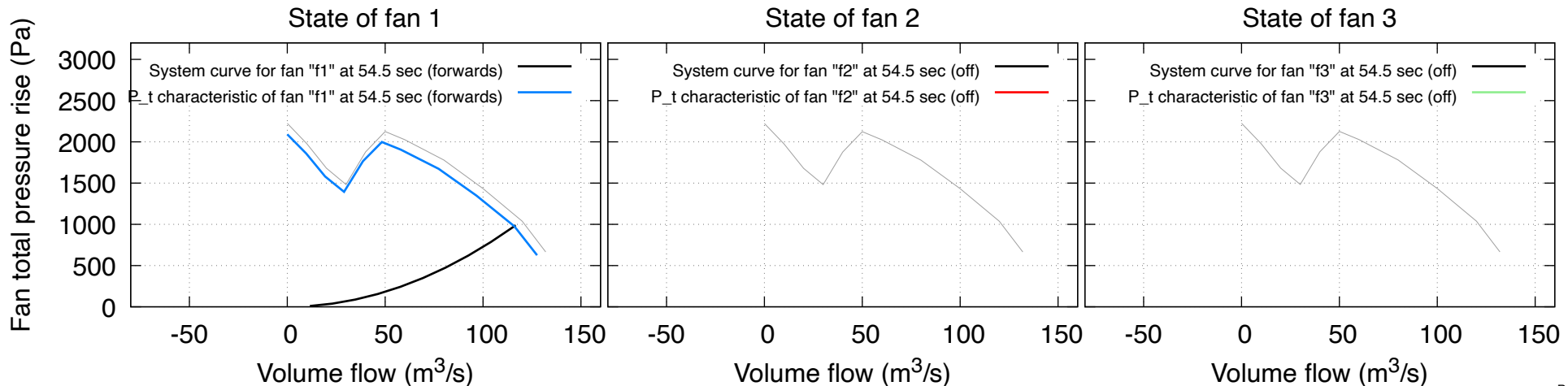
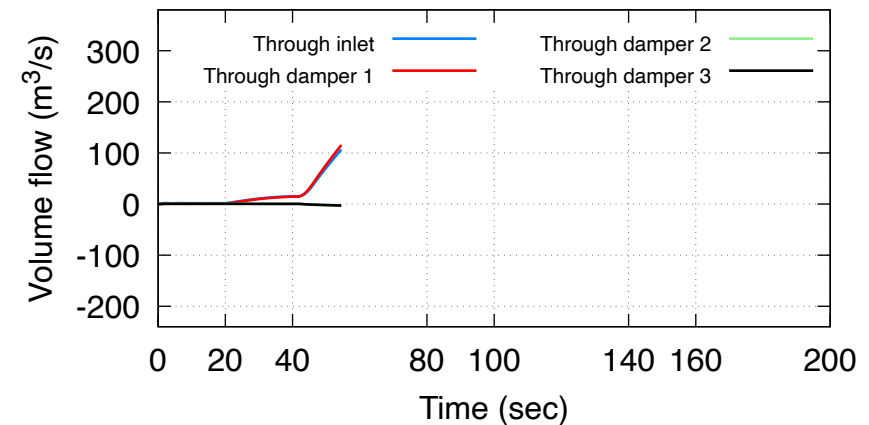
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Transient volume flows in the system



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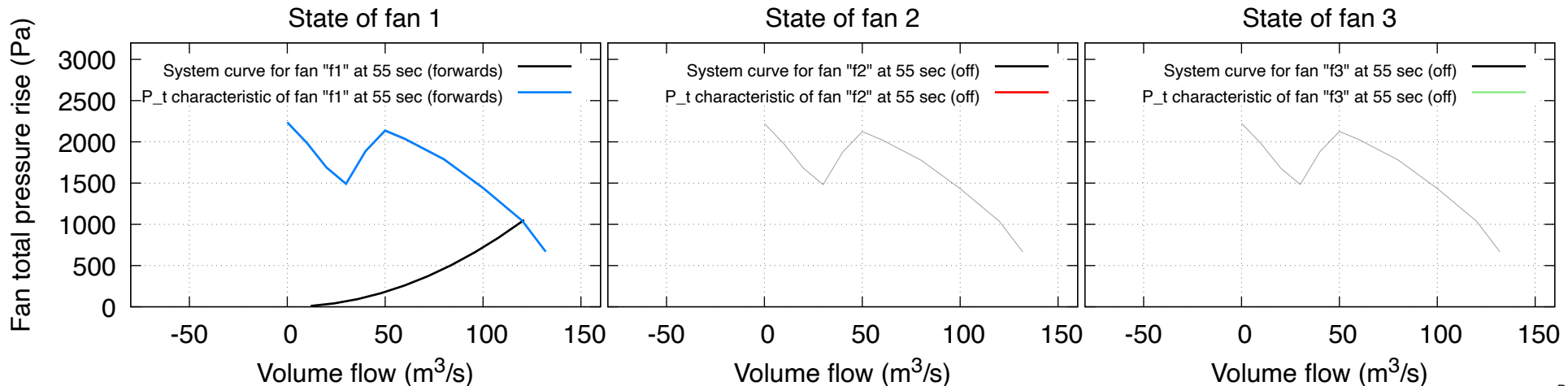
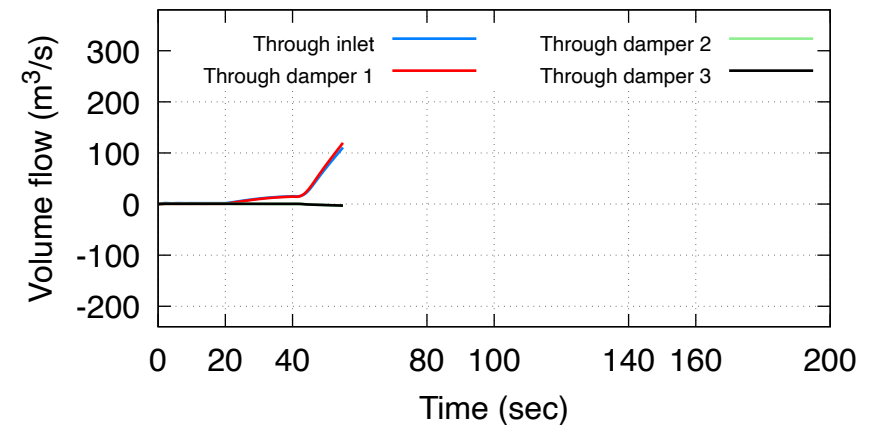
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Transient volume flows in the system



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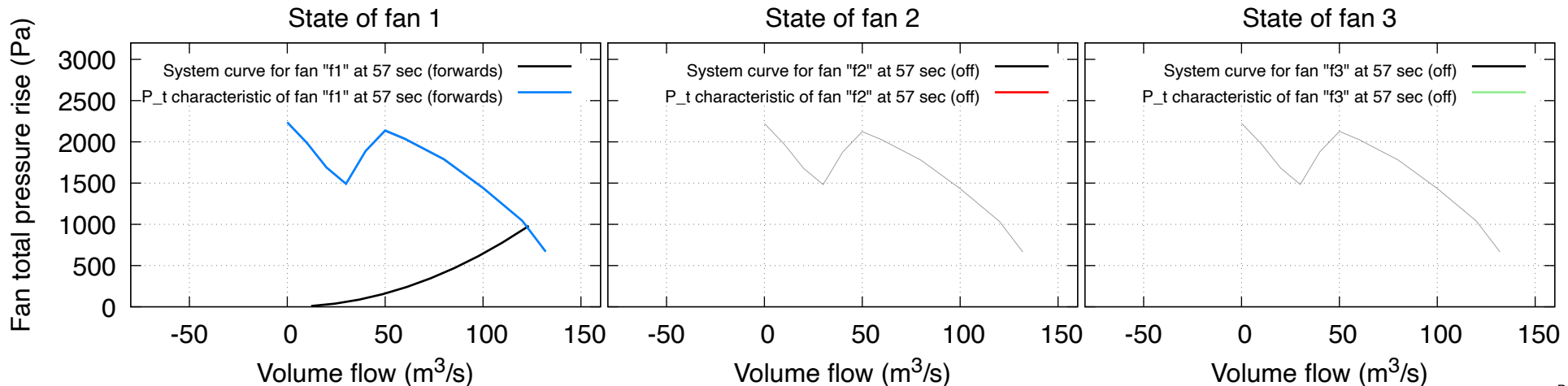
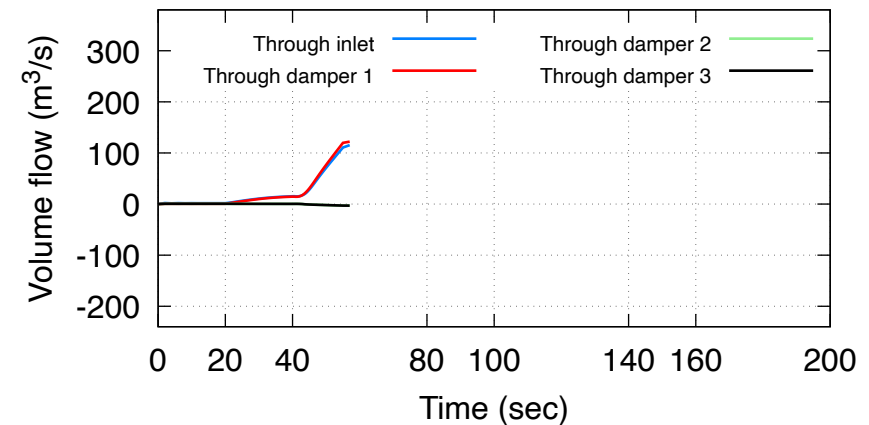
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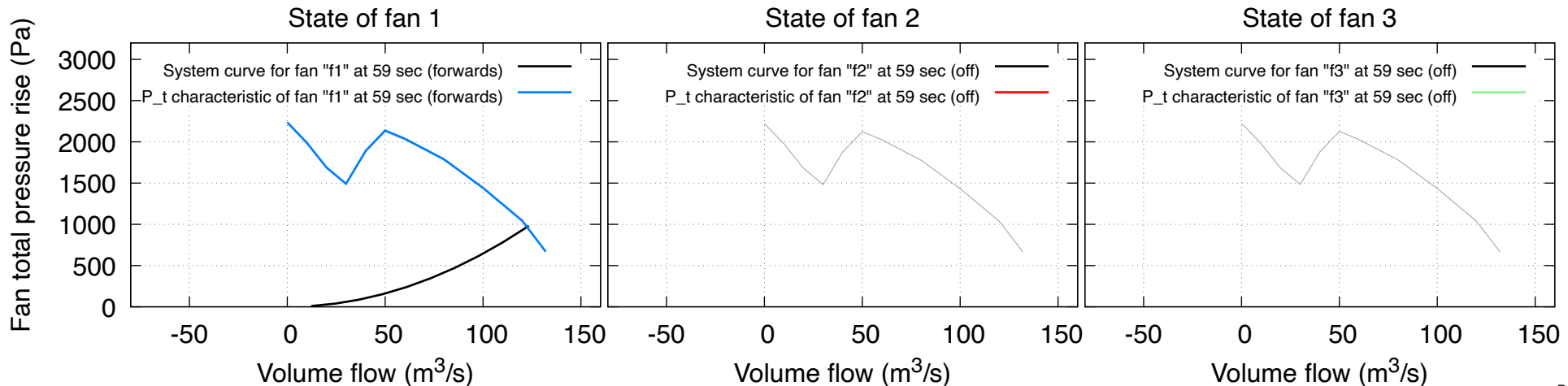
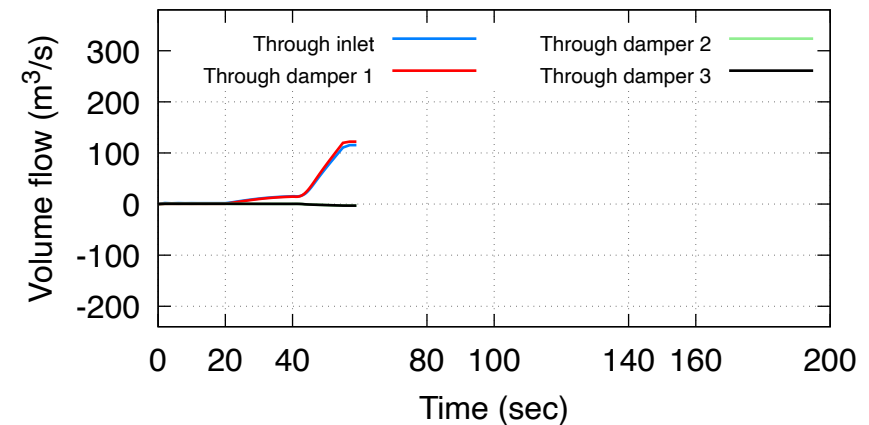
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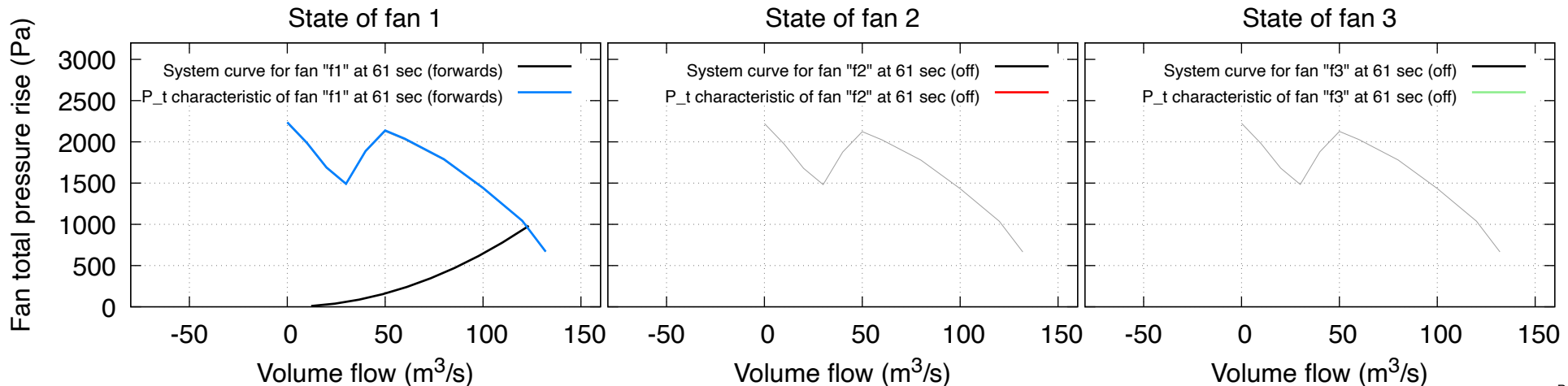
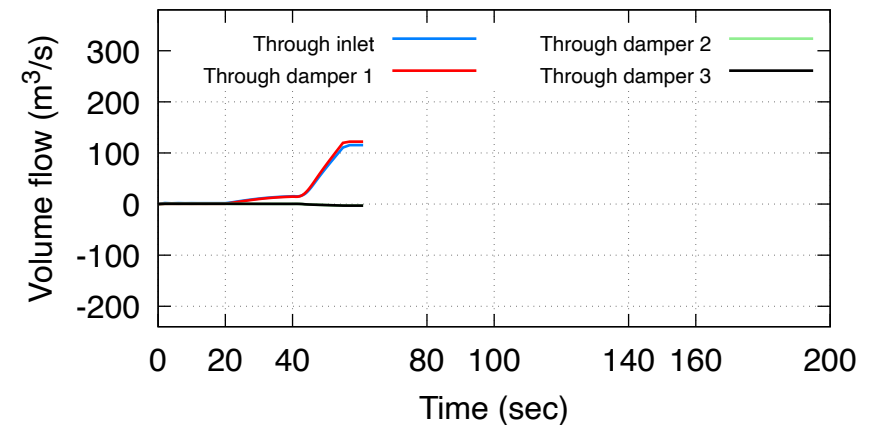
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Transient volume flows in the system



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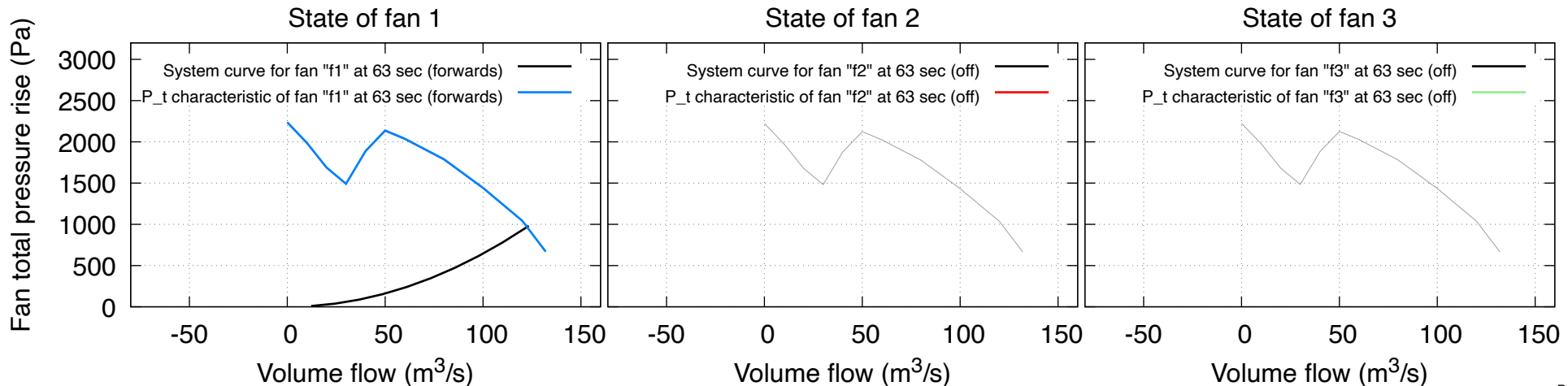
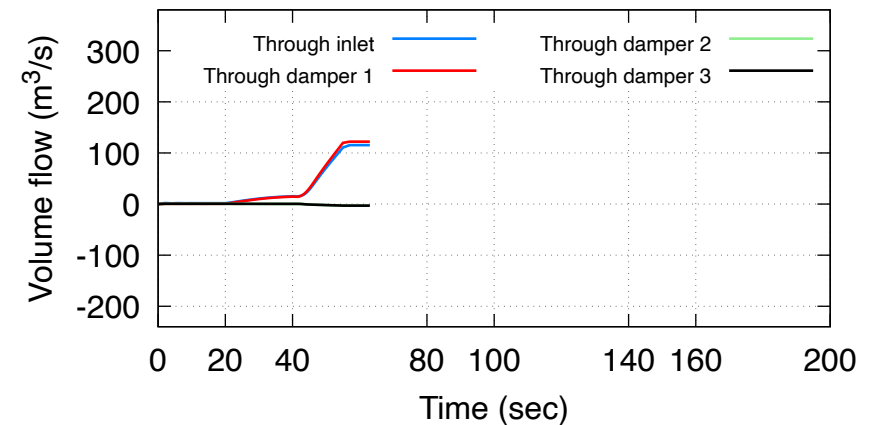
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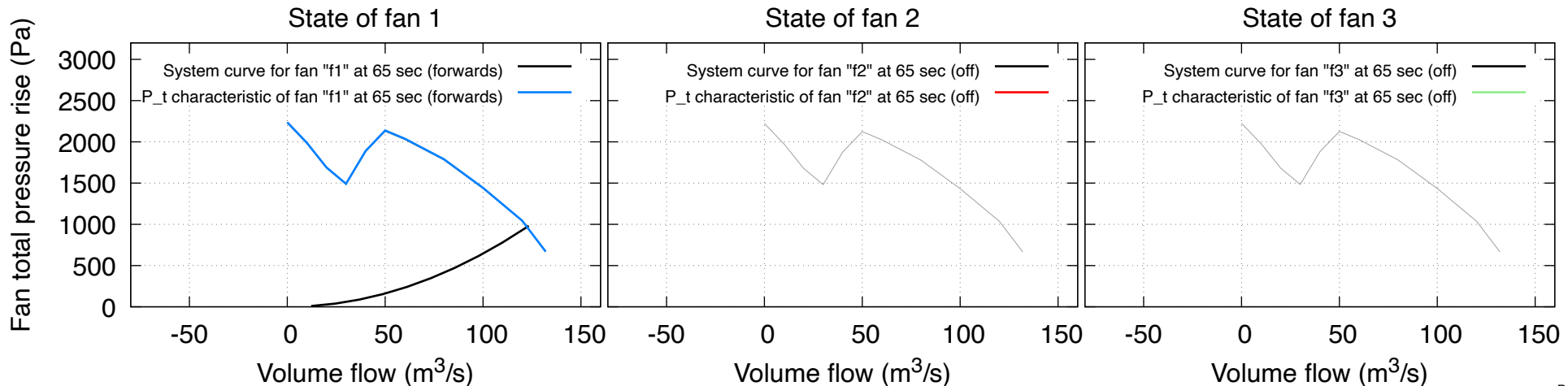
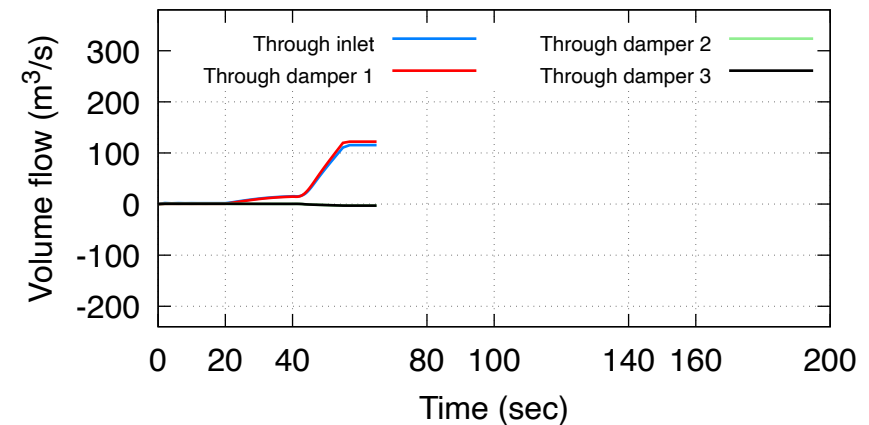
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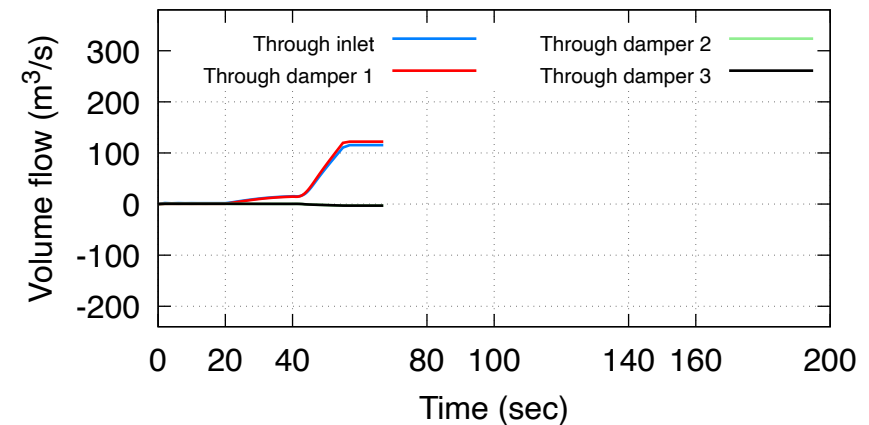
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Transient volume flows in the system



At 20 seconds, damper 1 opens

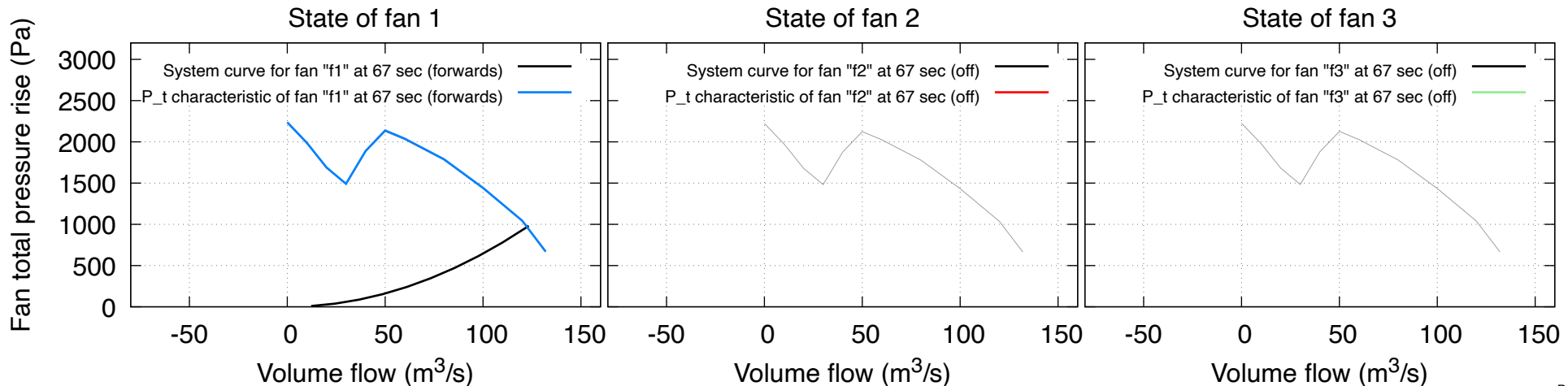
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

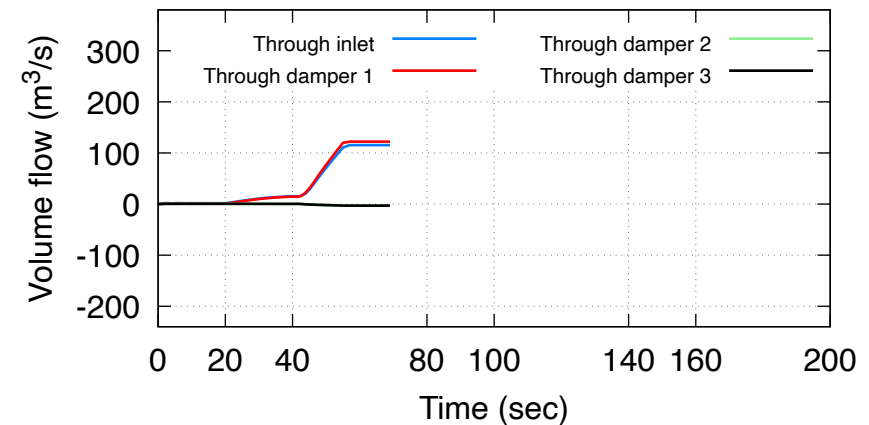
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Transient volume flows in the system



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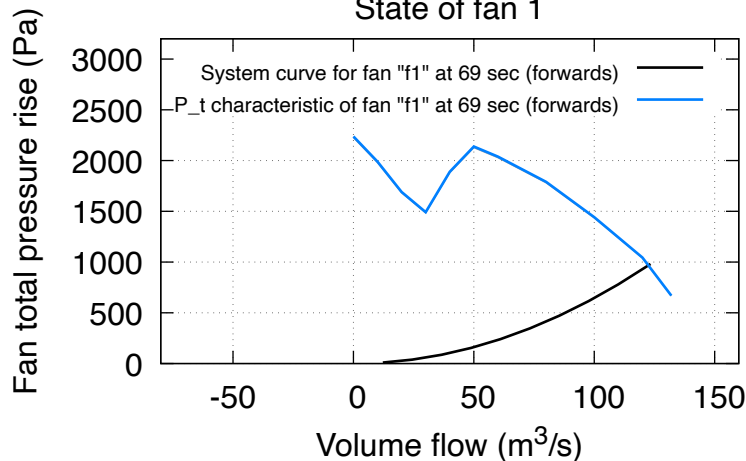
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

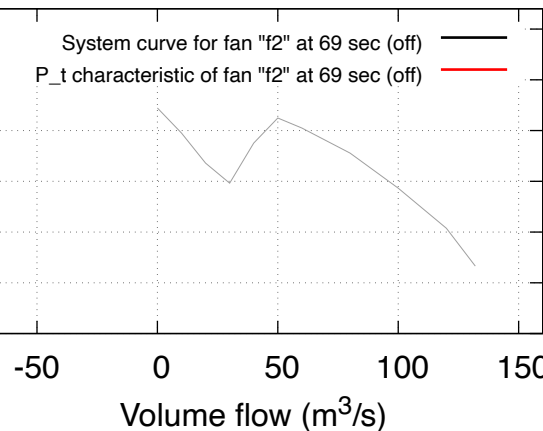
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

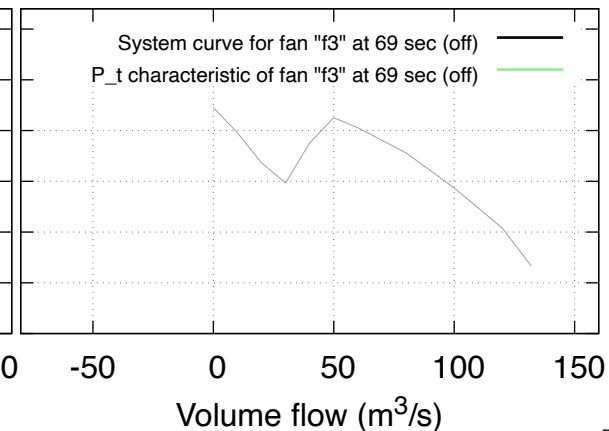
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

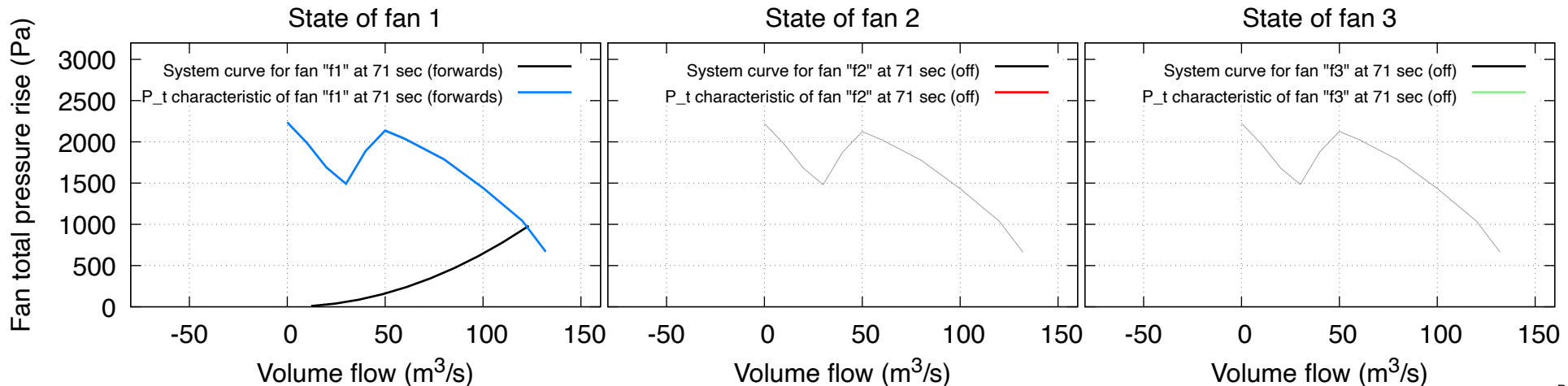
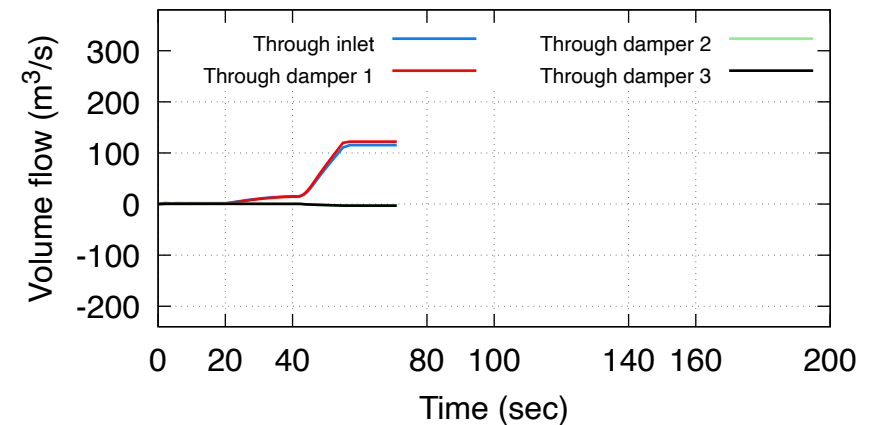
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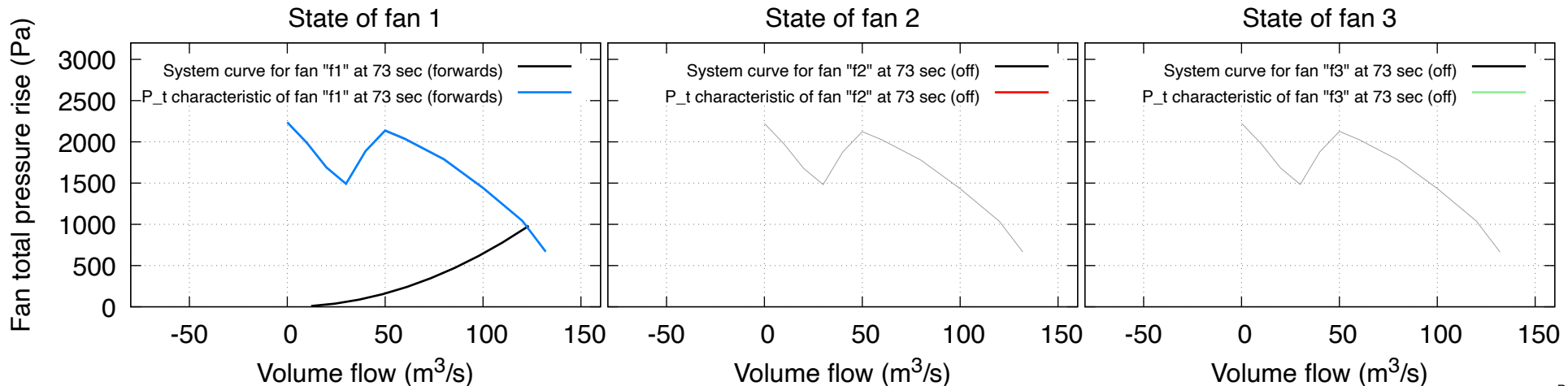
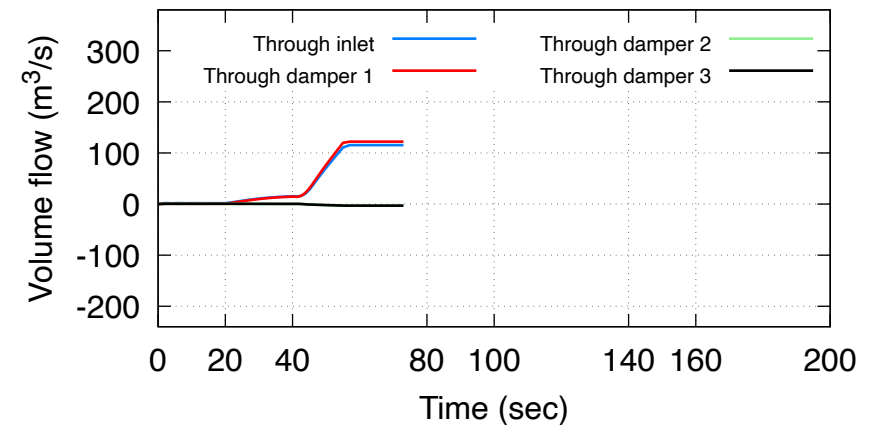
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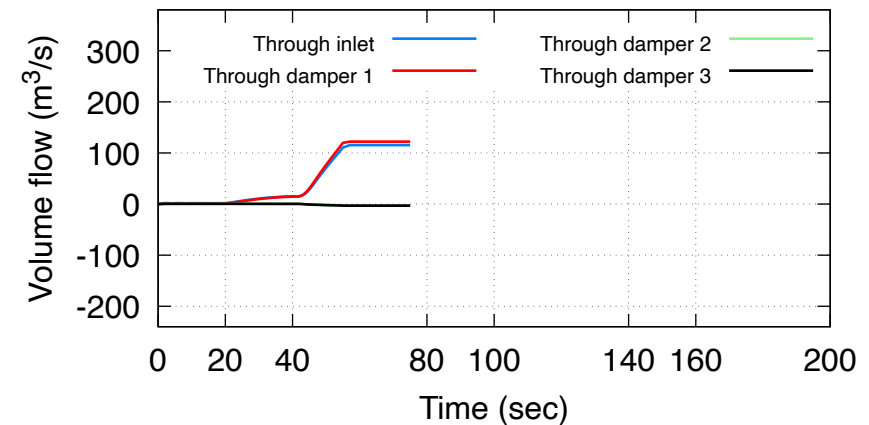
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

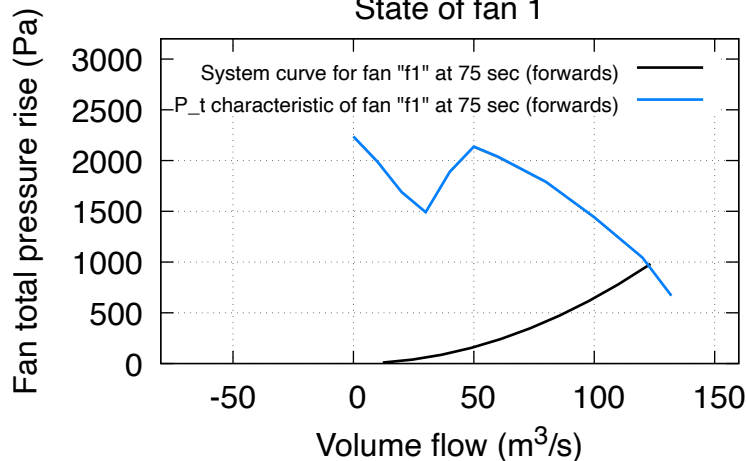
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

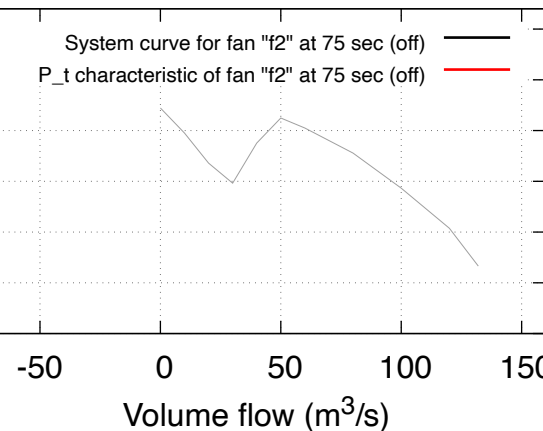
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

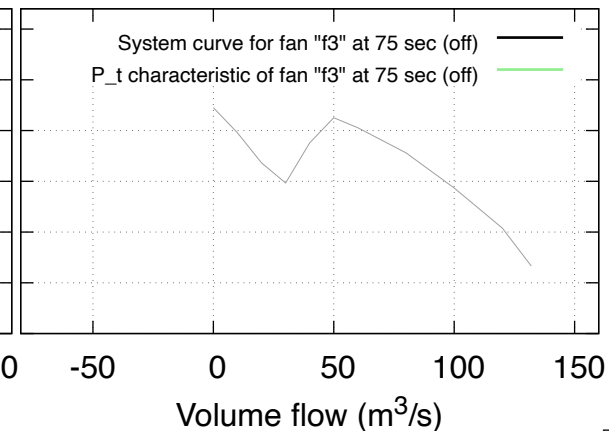
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

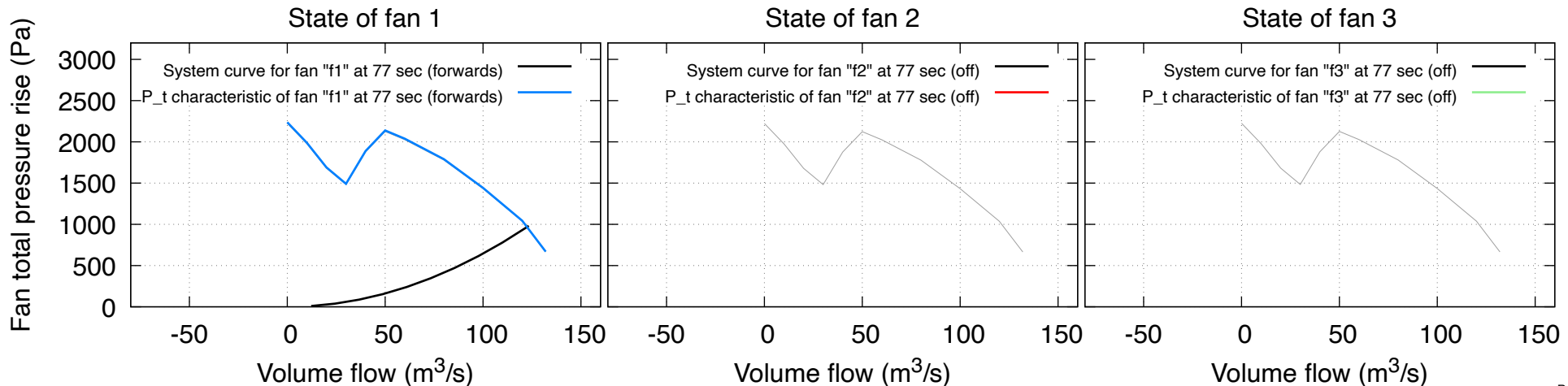
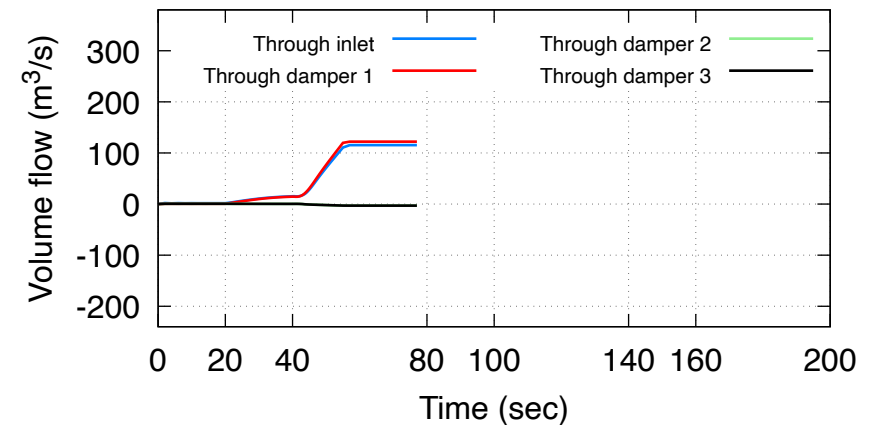
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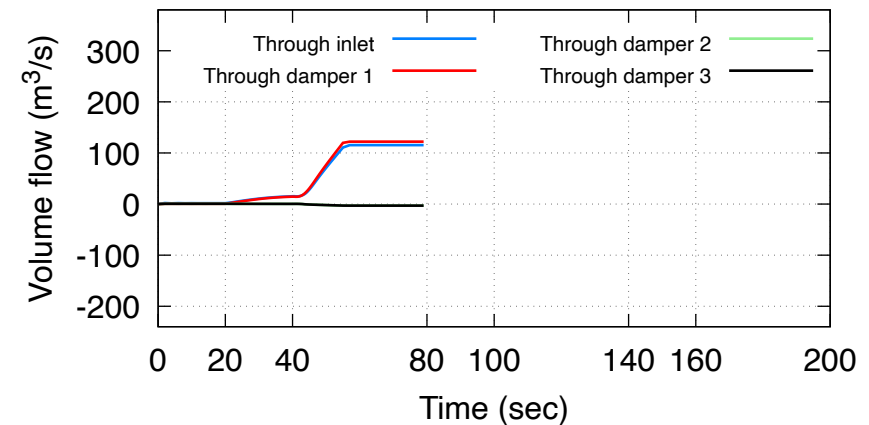
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At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

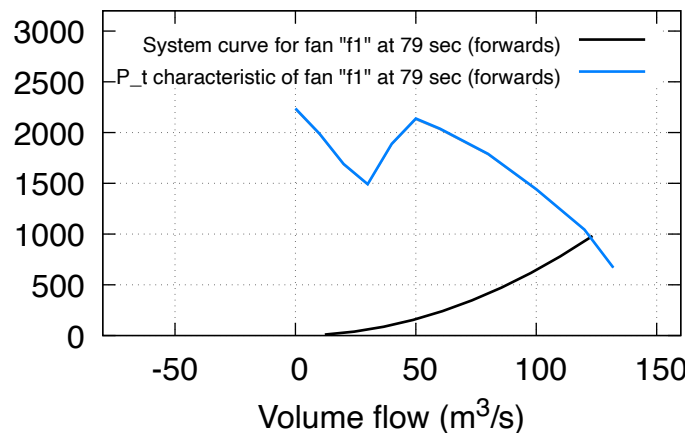
At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

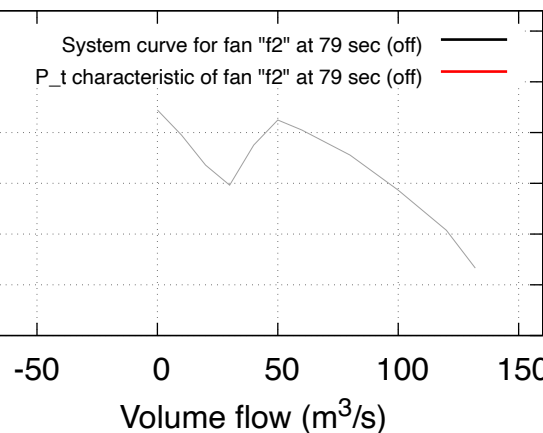
At 160 seconds, fan 3 starts

Fan total pressure rise (Pa)

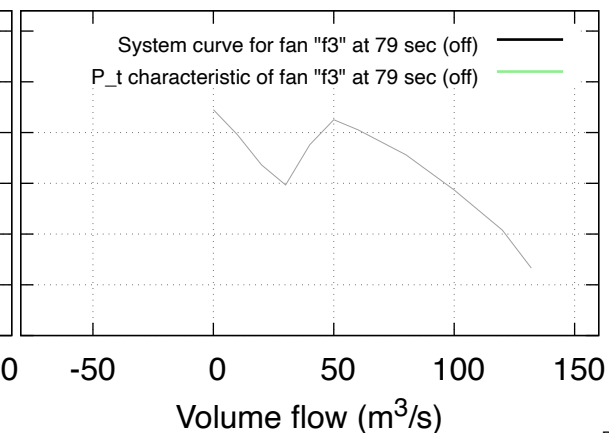
State of fan 1



State of fan 2



State of fan 3



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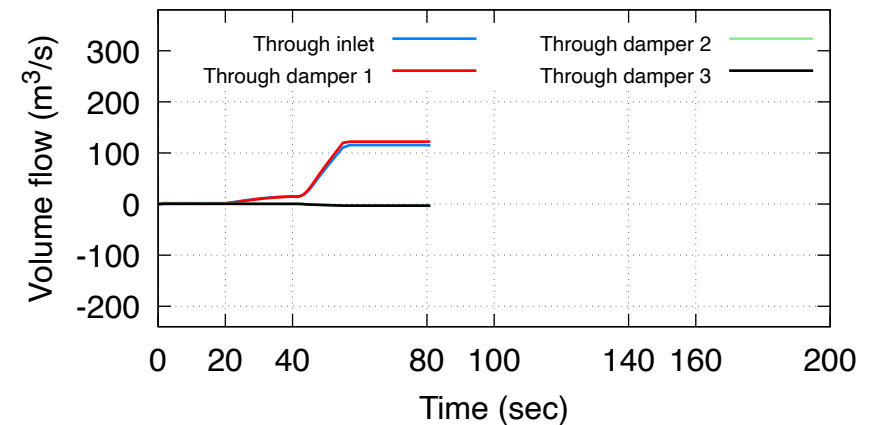
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Transient volume flows in the system



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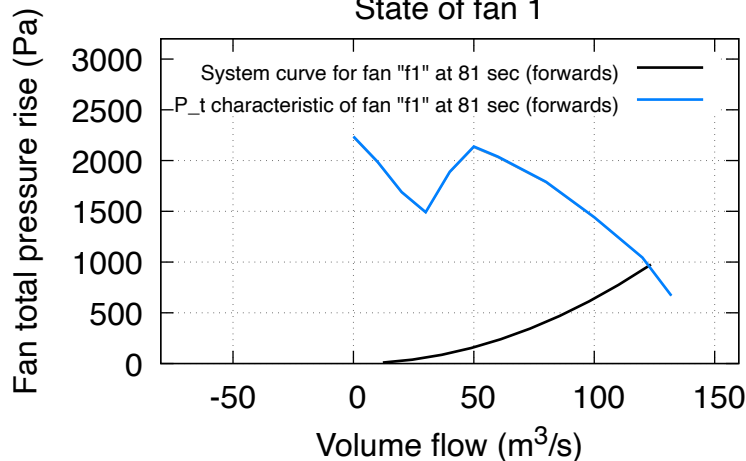
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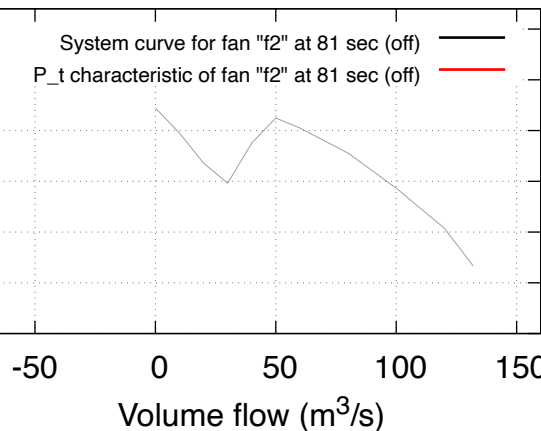
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At 160 seconds, fan 3 starts

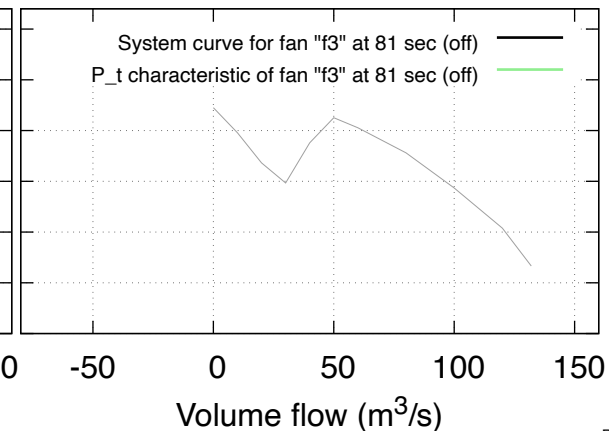
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

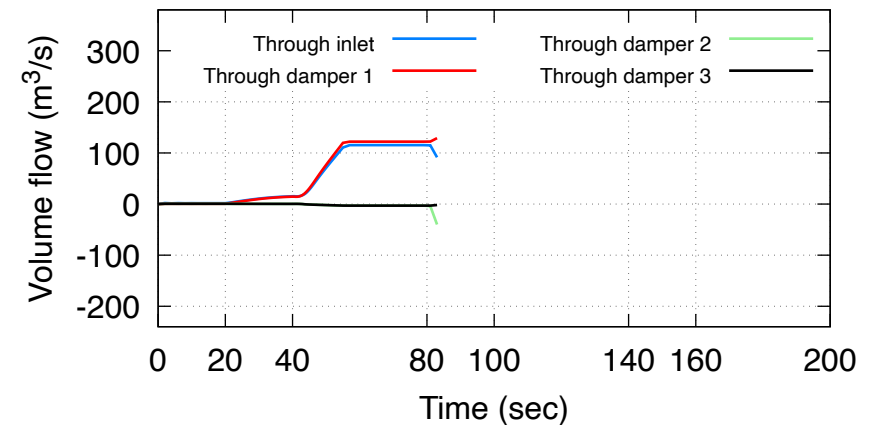
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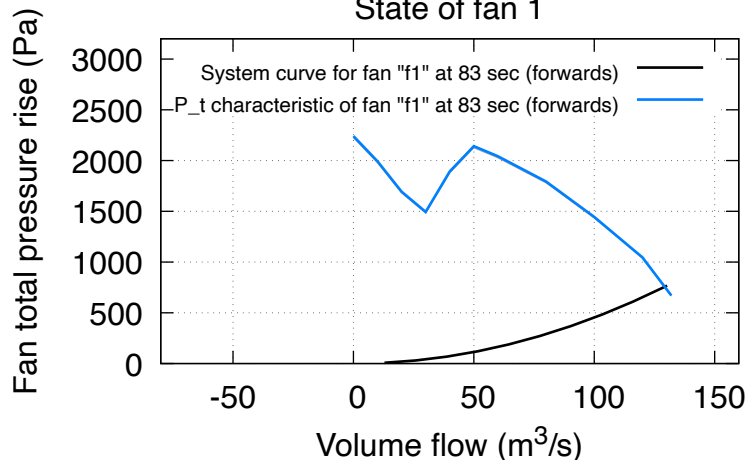
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At 100 seconds, fan 2 starts

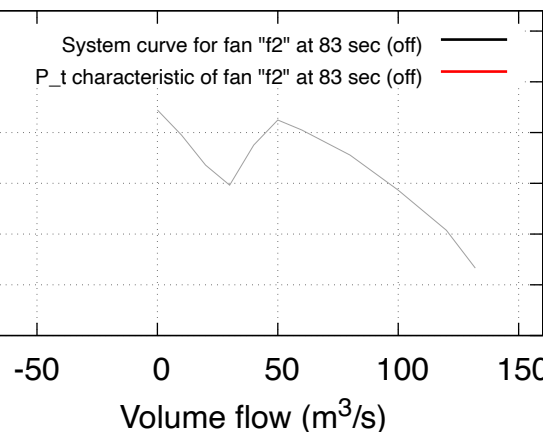
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

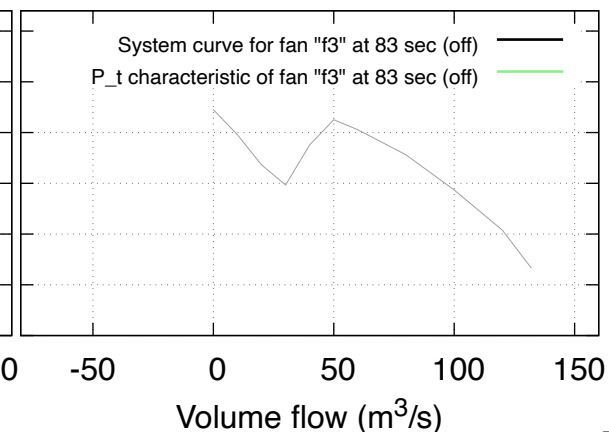
State of fan 1



State of fan 2



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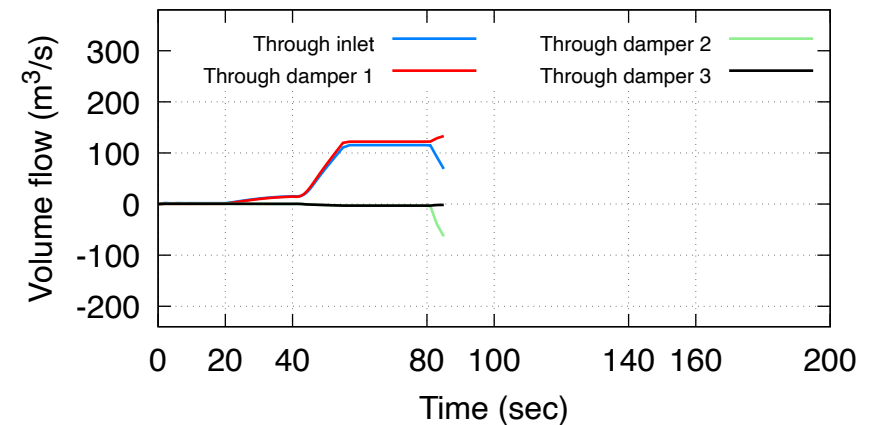
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

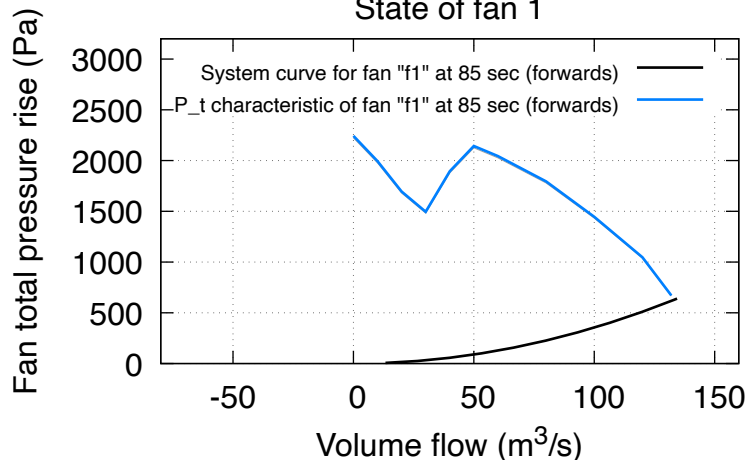
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

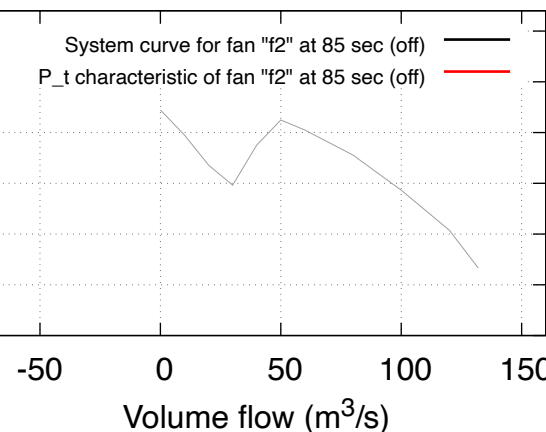
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

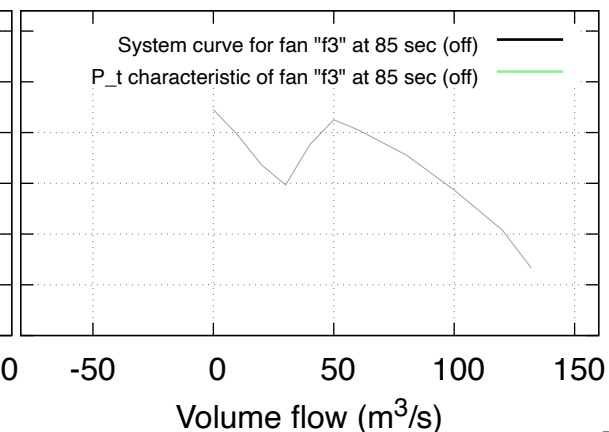
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

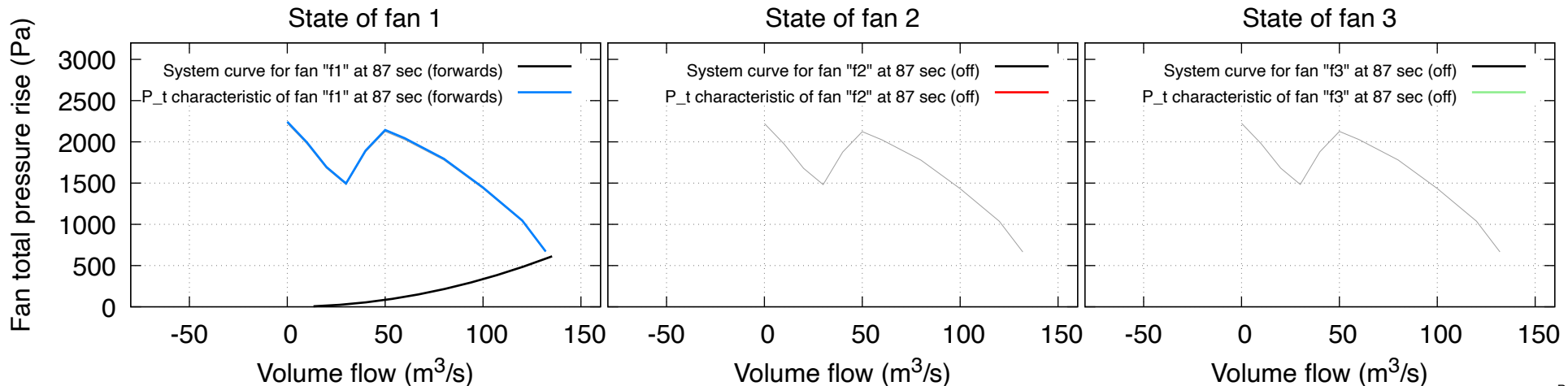
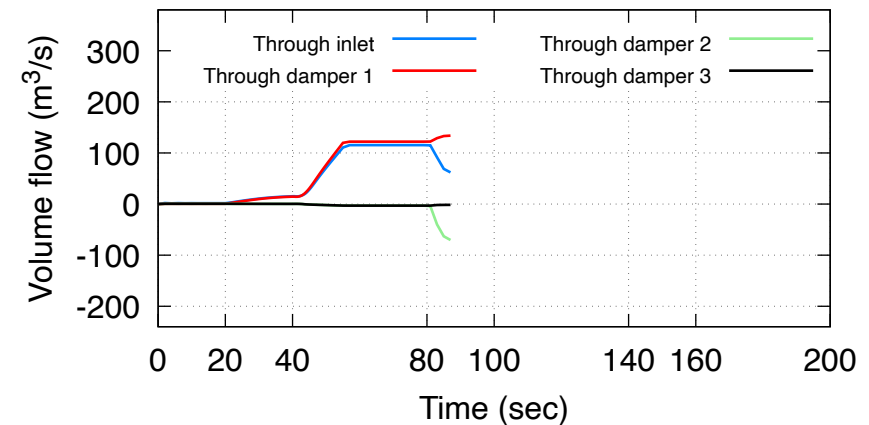
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Transient volume flows in the system



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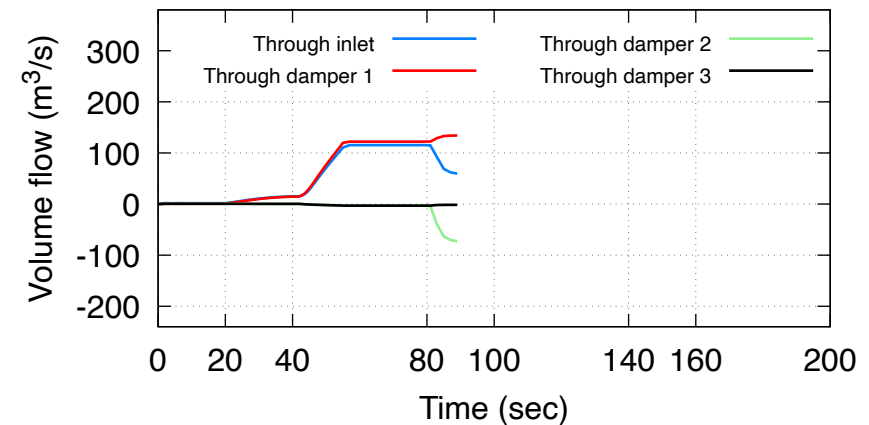
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Transient volume flows in the system



At 20 seconds, damper 1 opens

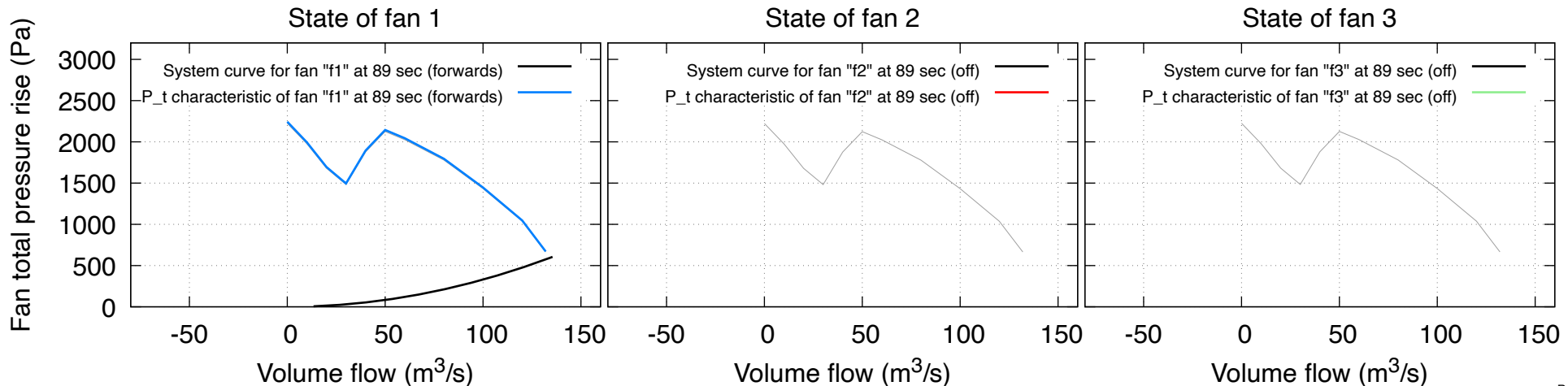
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

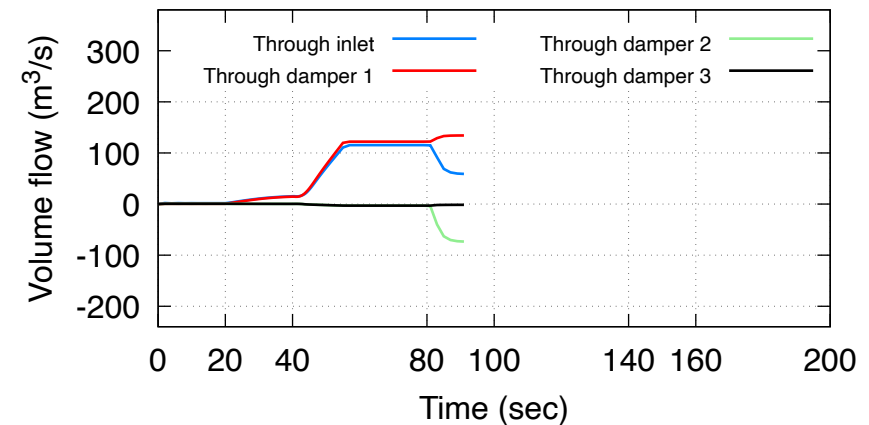
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Transient volume flows in the system



At 20 seconds, damper 1 opens

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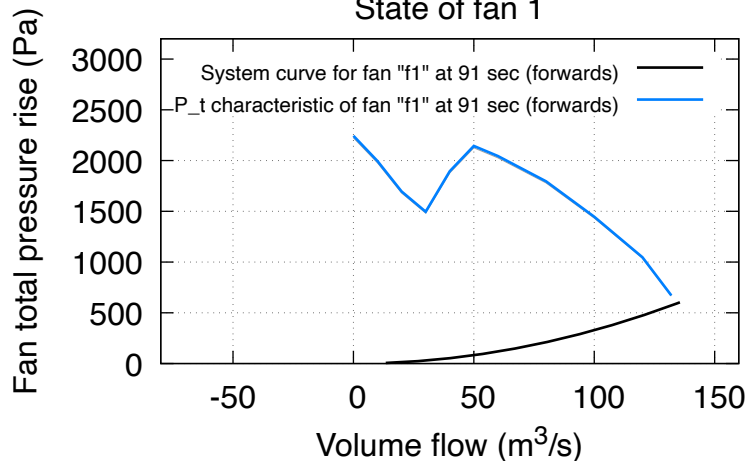
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

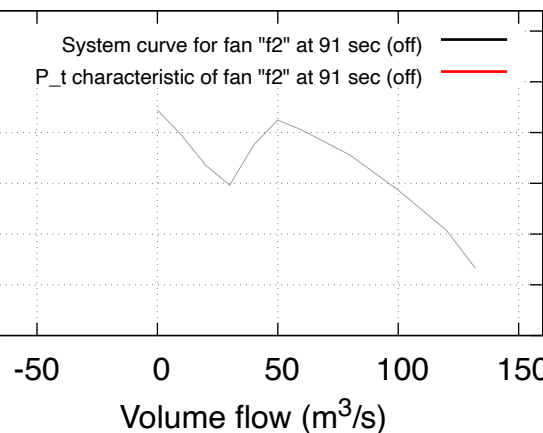
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

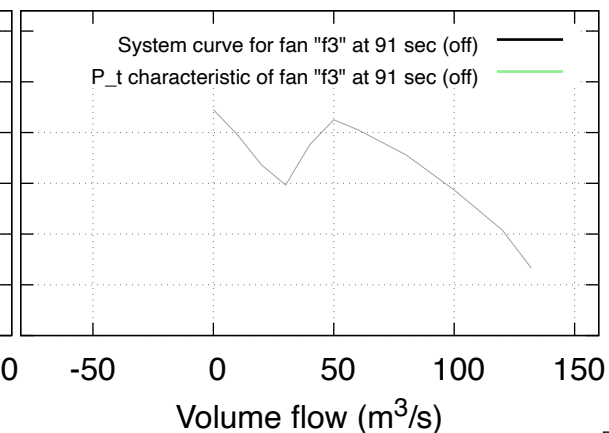
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

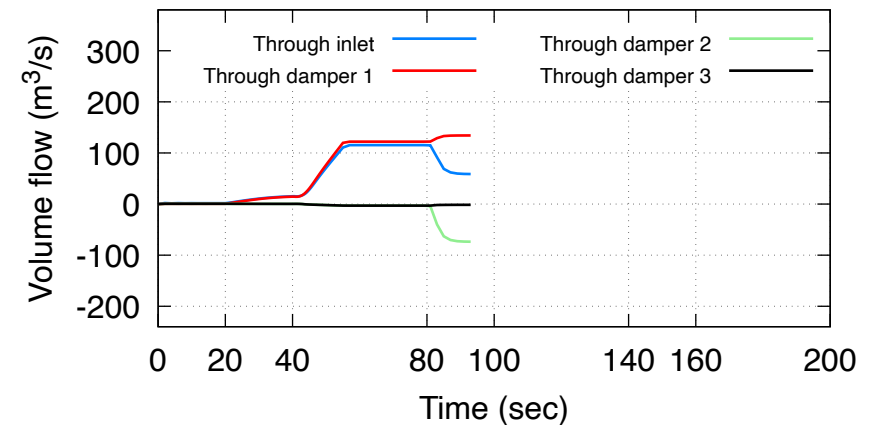
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

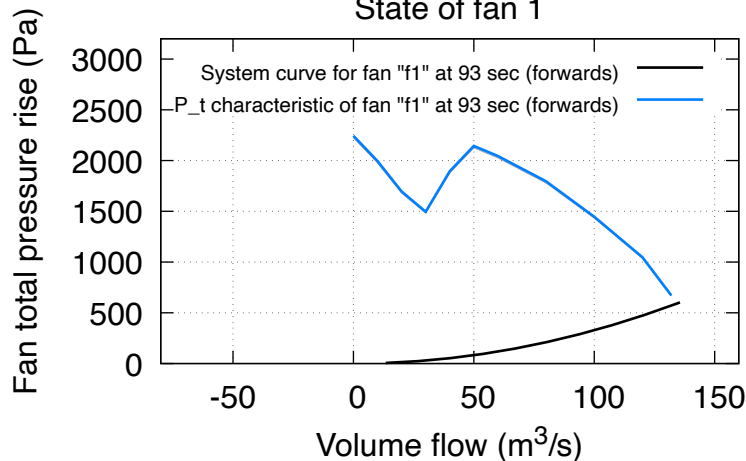
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

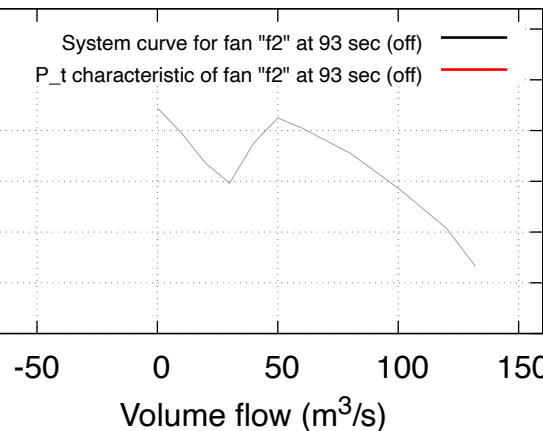
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

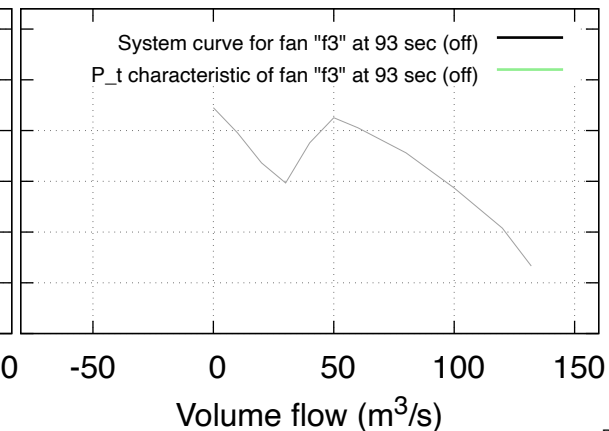
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

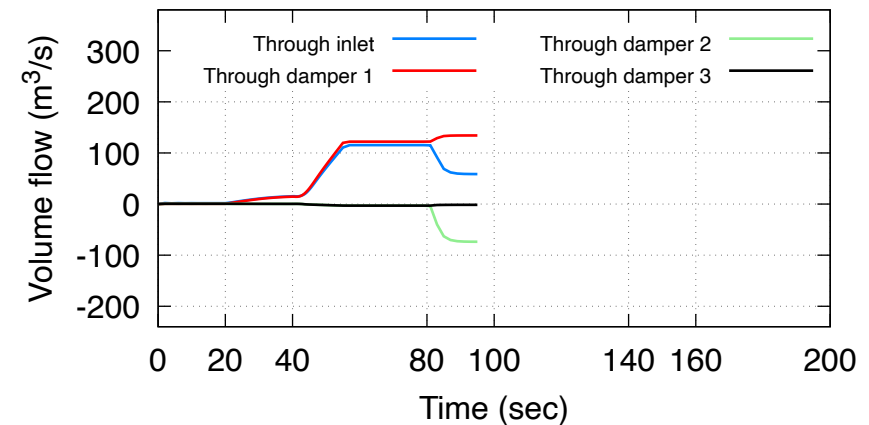
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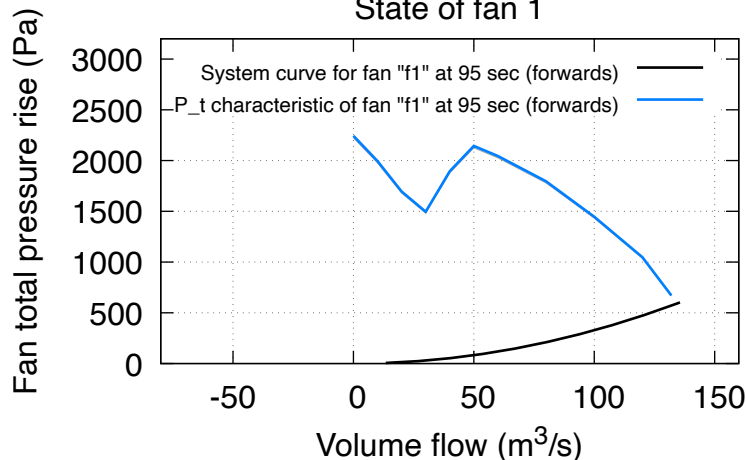
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

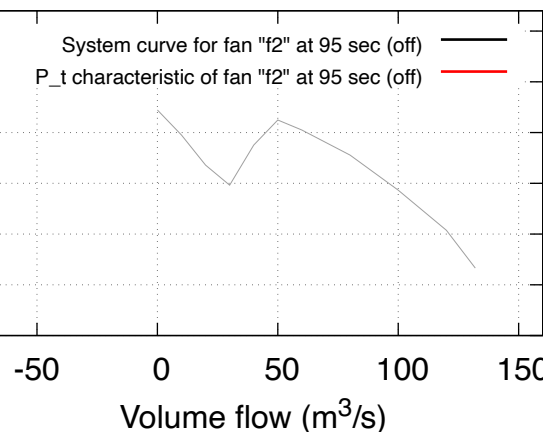
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

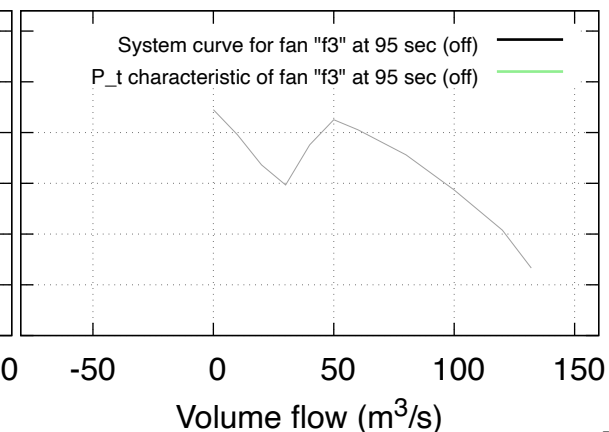
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

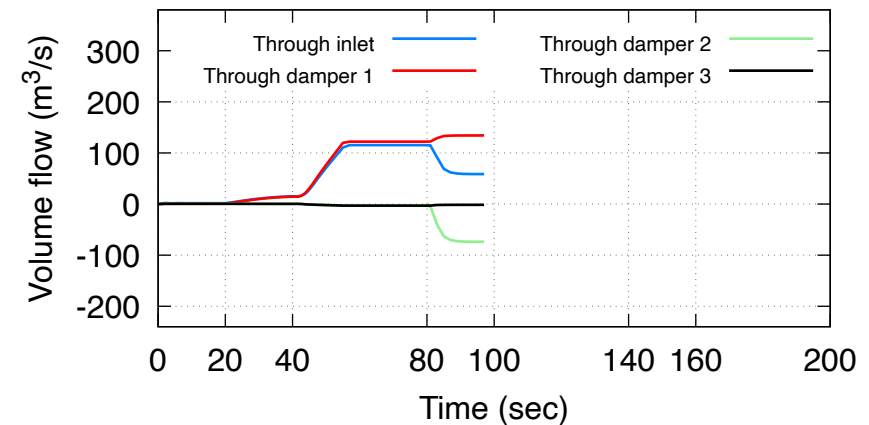
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At 20 seconds, damper 1 opens

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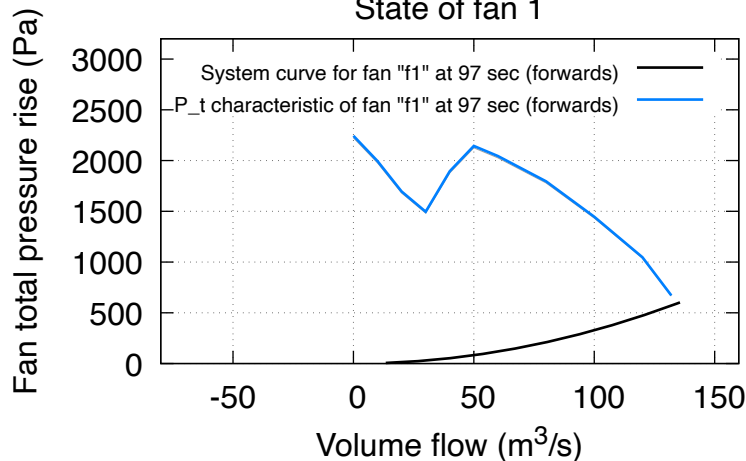
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

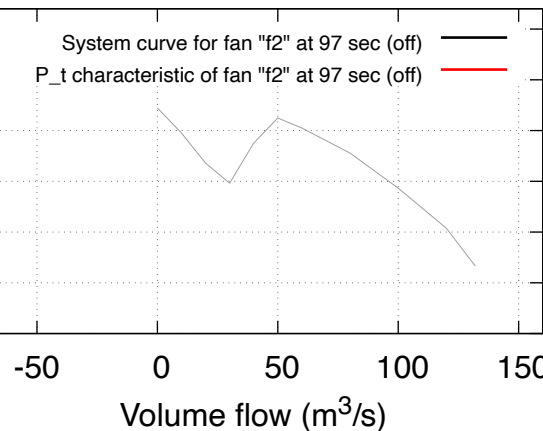
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

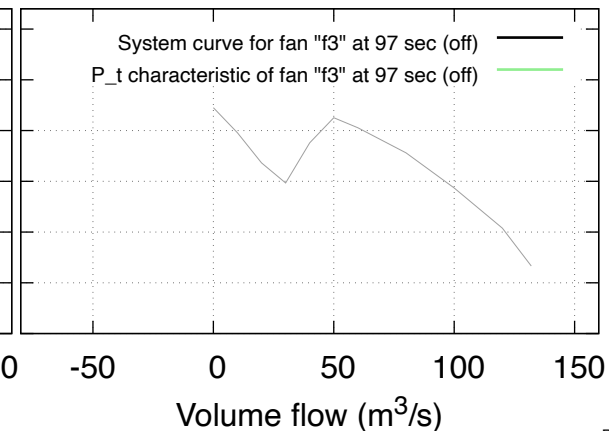
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

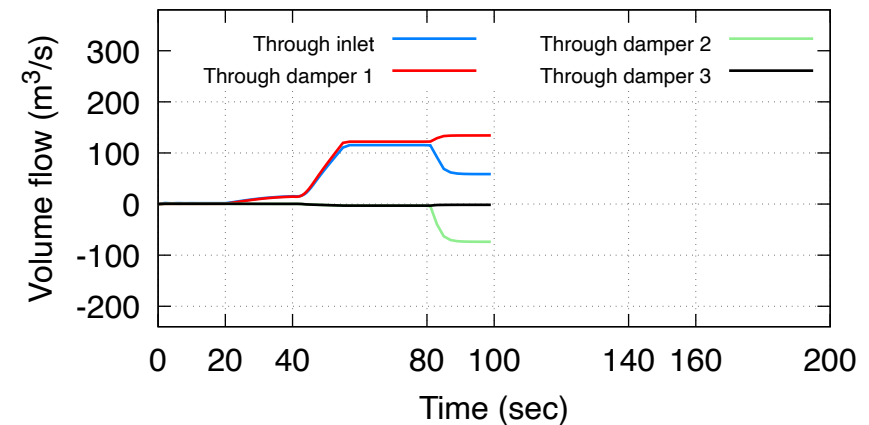
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

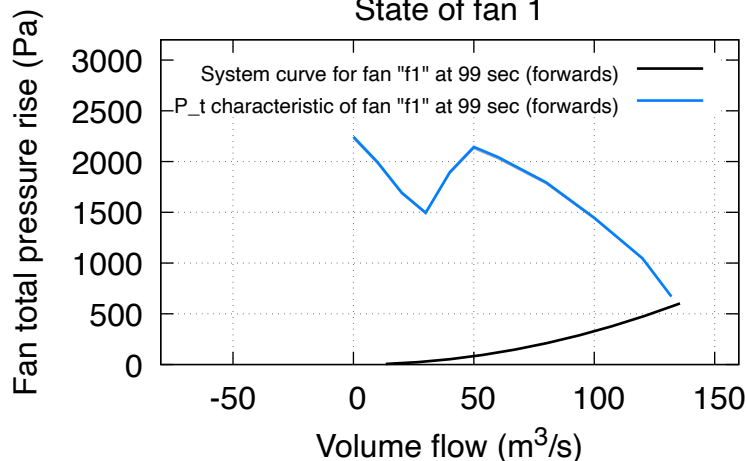
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

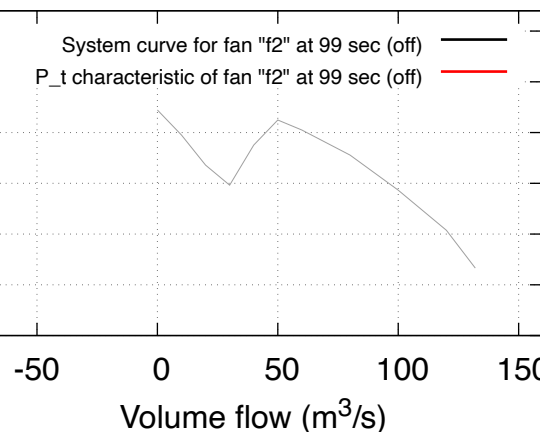
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

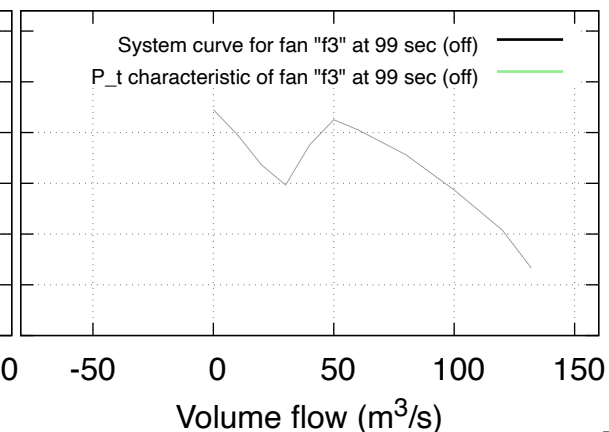
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

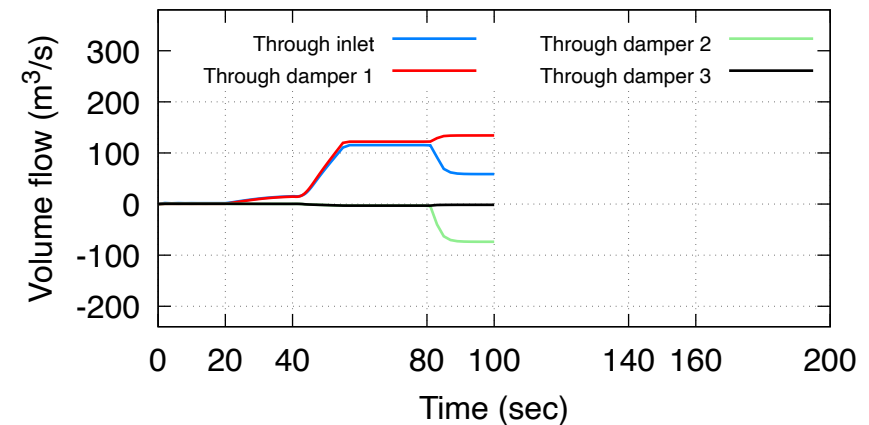
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Transient volume flows in the system



At 20 seconds, damper 1 opens

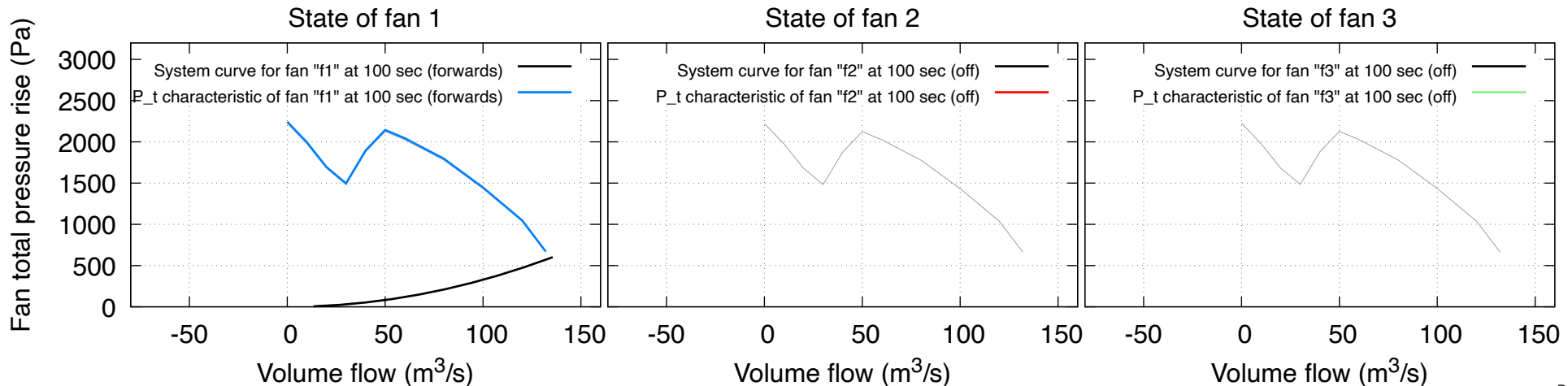
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

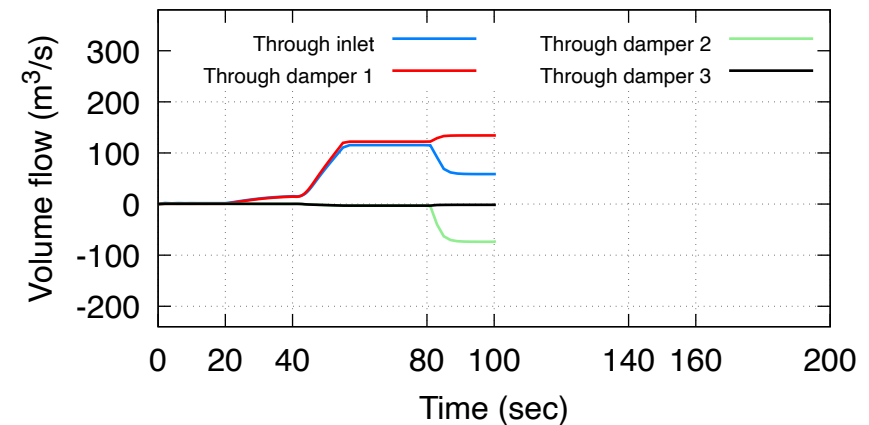
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At 20 seconds, damper 1 opens

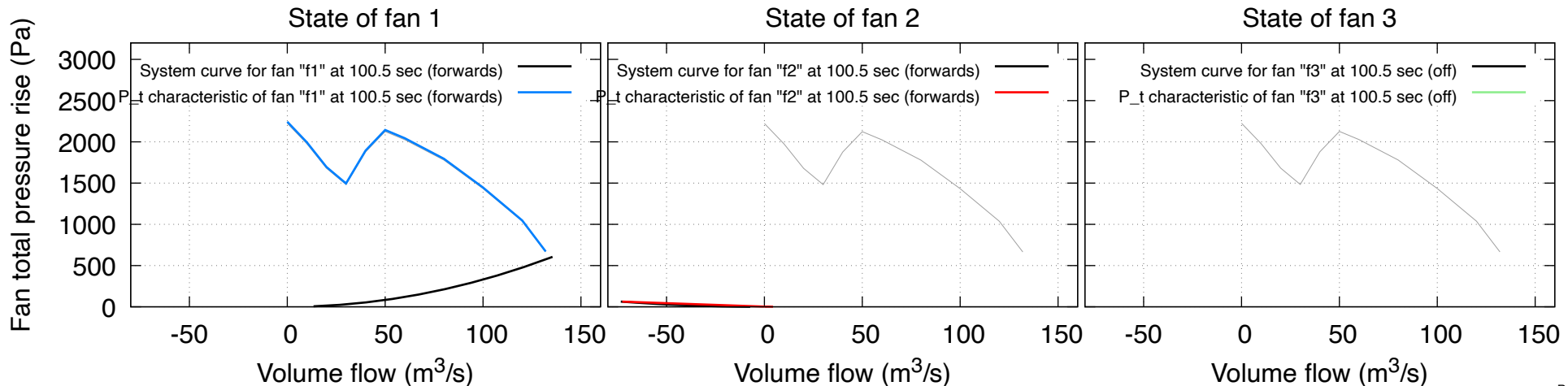
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

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How not to run fans in parallel

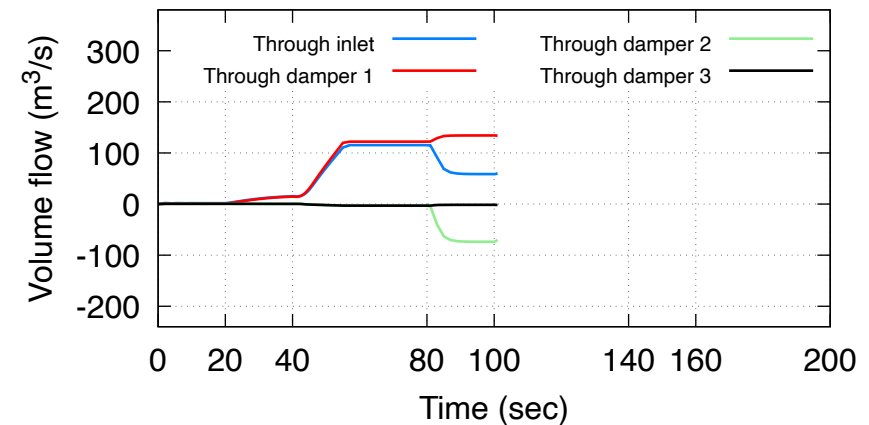
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Transient volume flows in the system



At 20 seconds, damper 1 opens

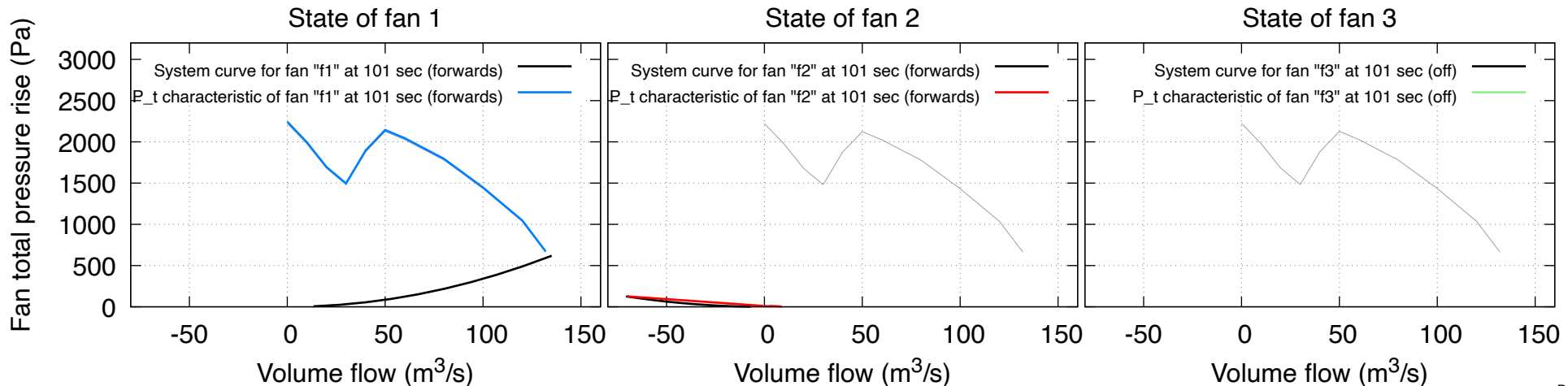
At 40 seconds, fan 1 starts

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How not to run fans in parallel

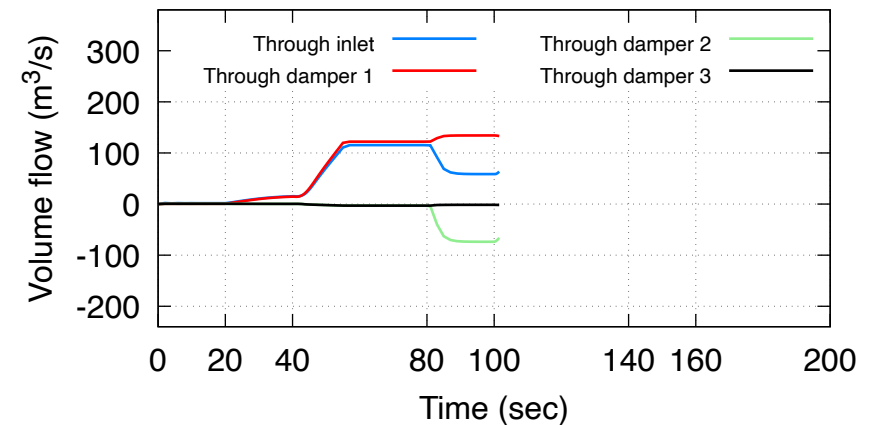
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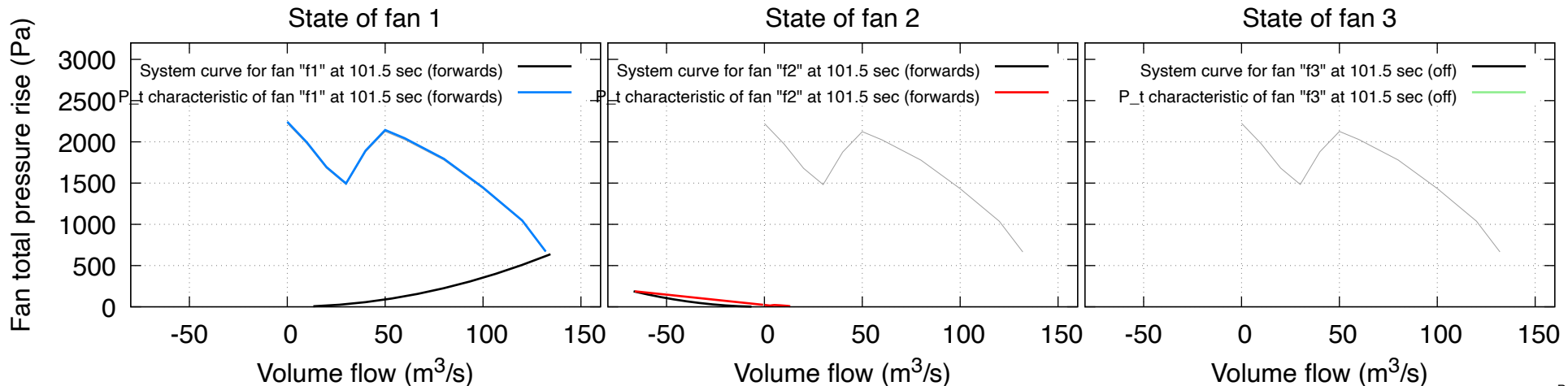
At 40 seconds, fan 1 starts

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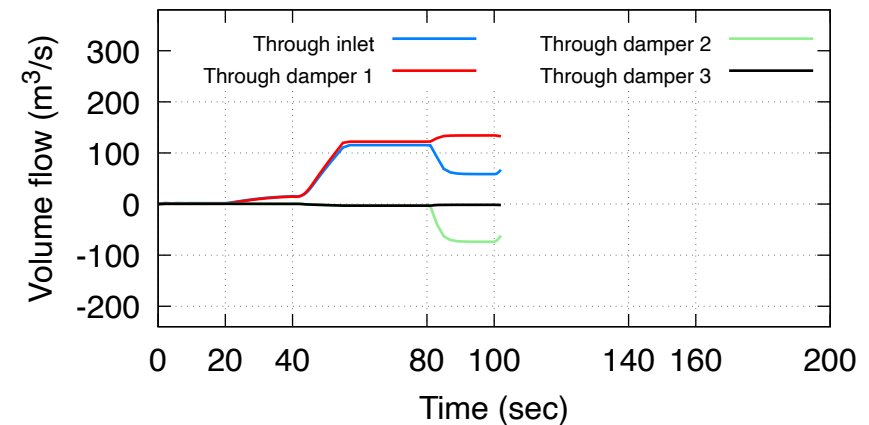
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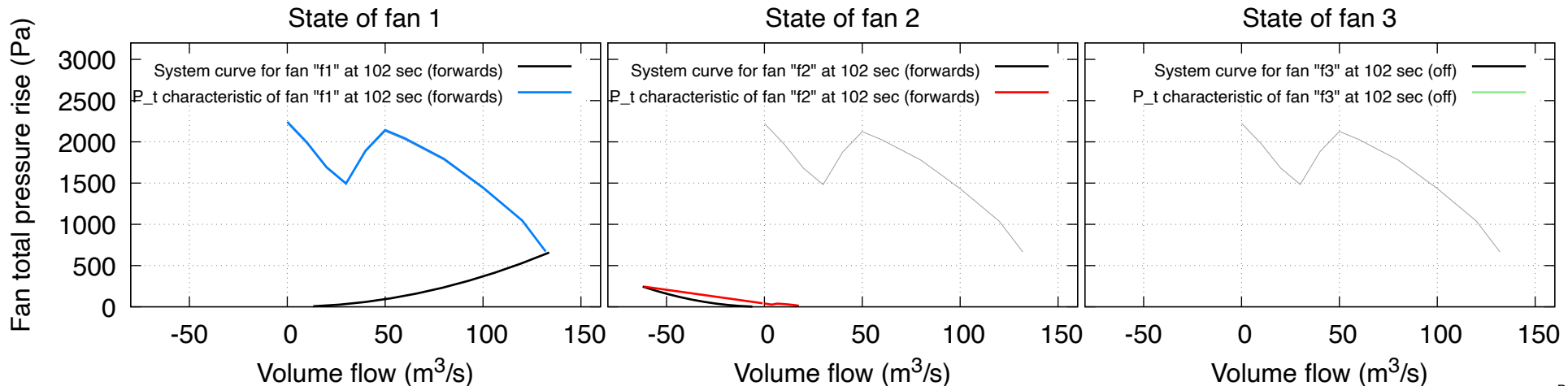
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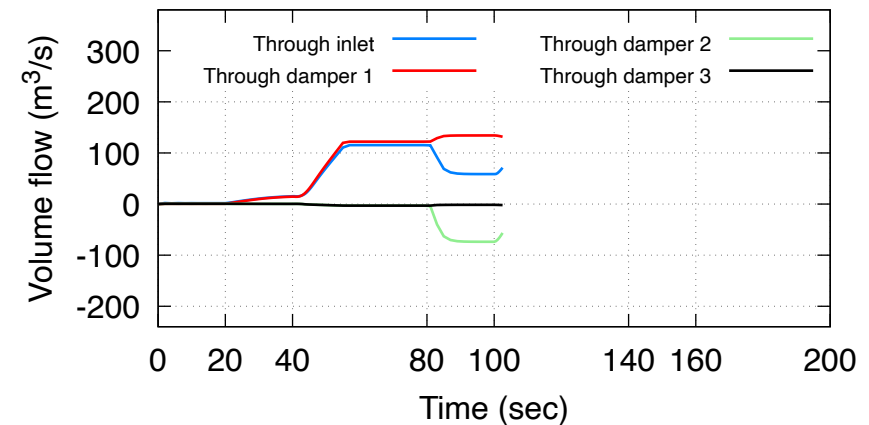
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At 20 seconds, damper 1 opens

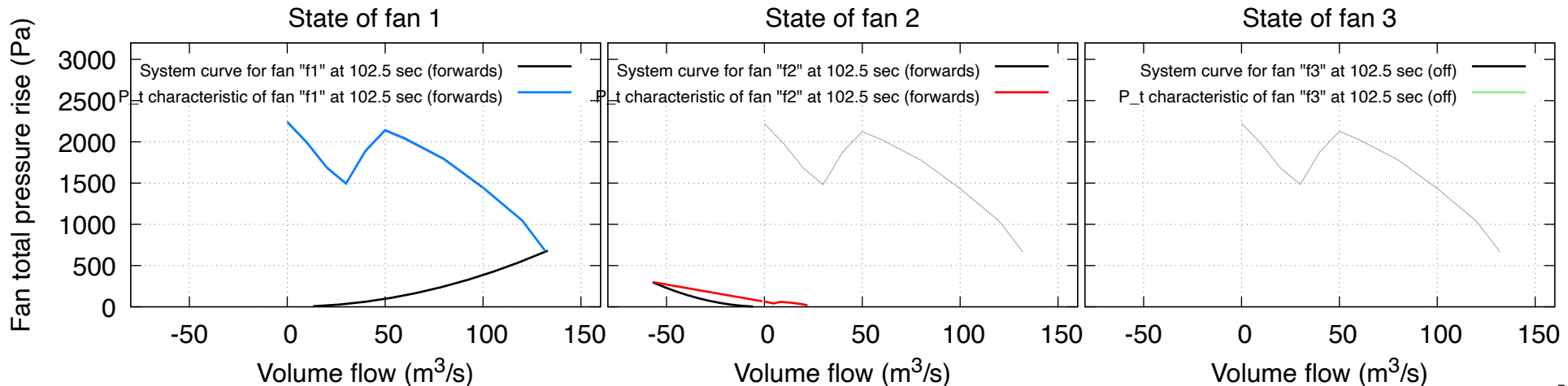
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

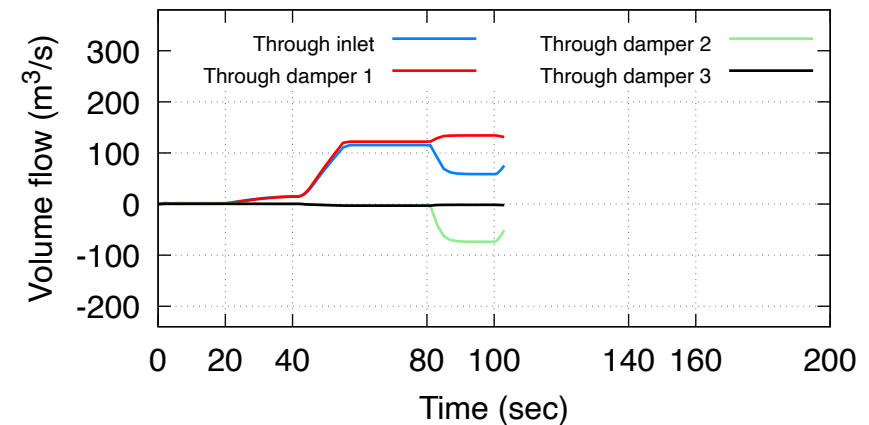
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At 20 seconds, damper 1 opens

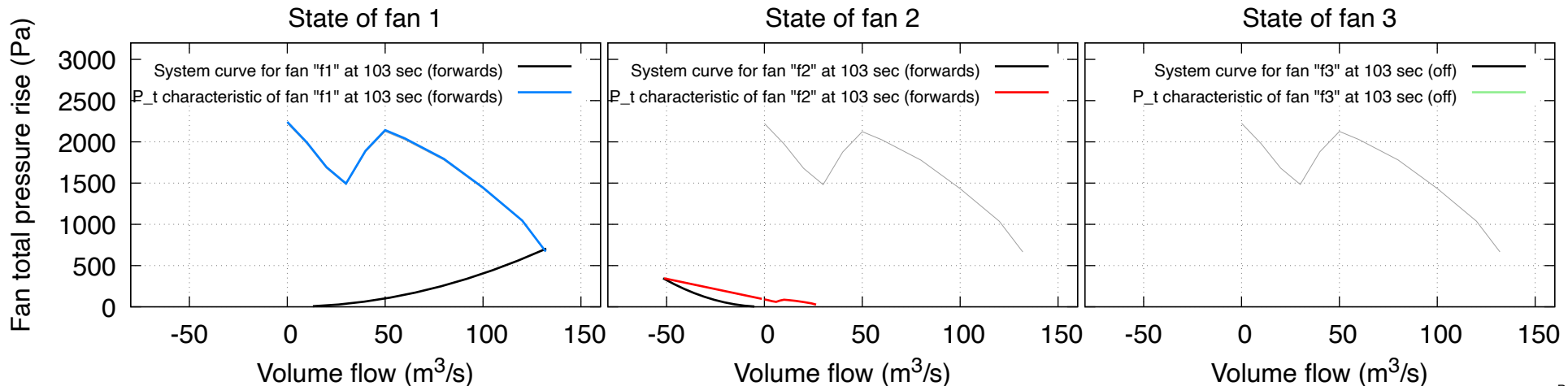
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

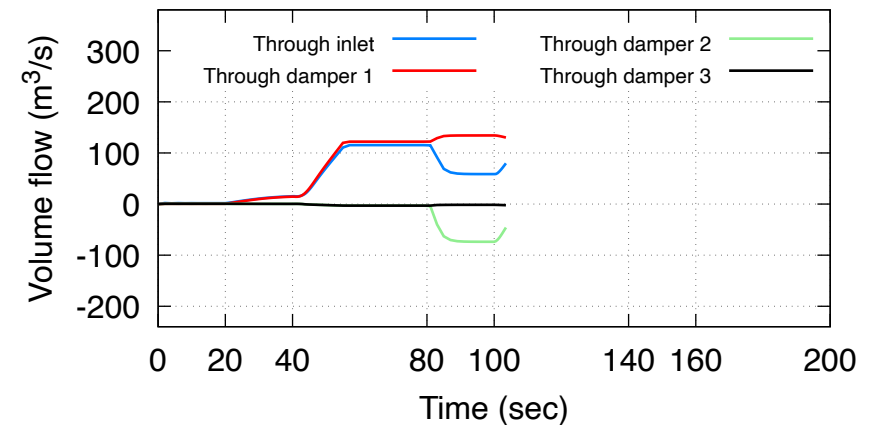
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At 20 seconds, damper 1 opens

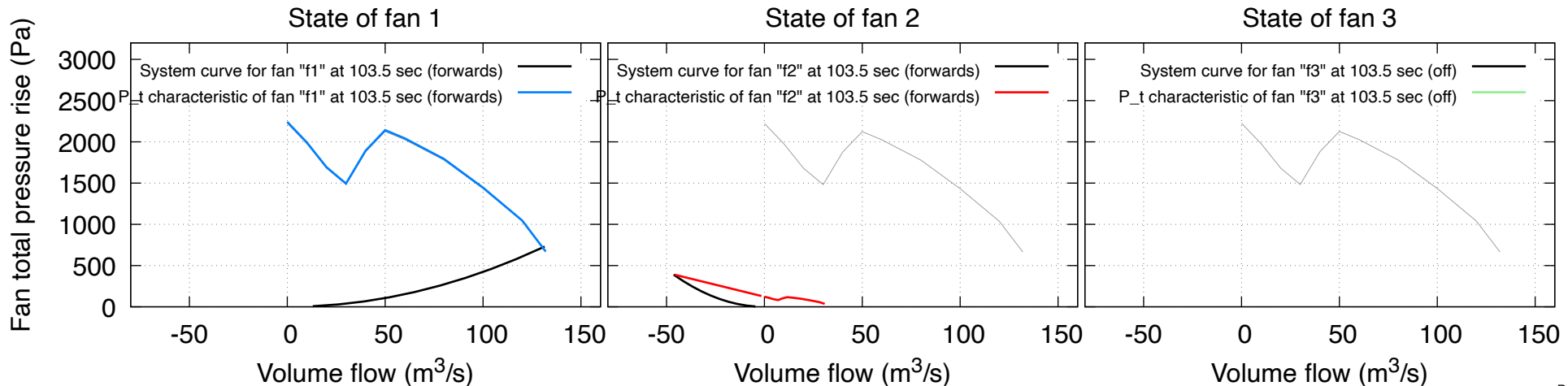
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



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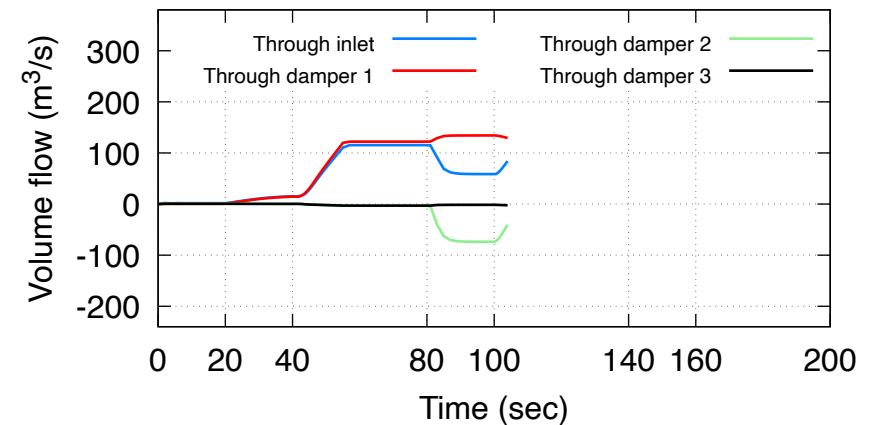
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

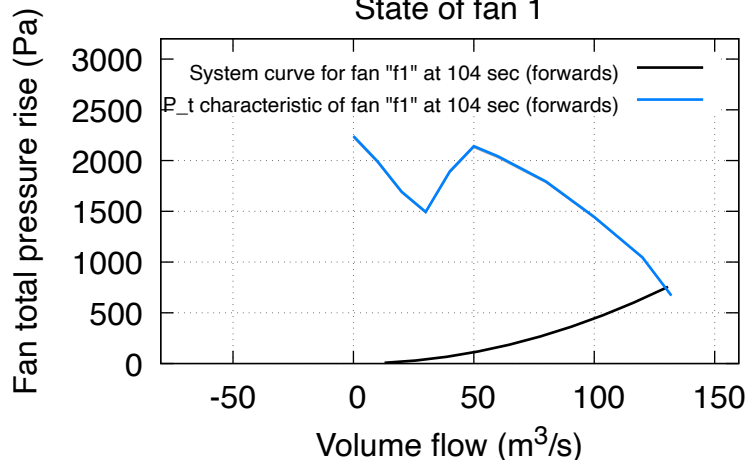
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

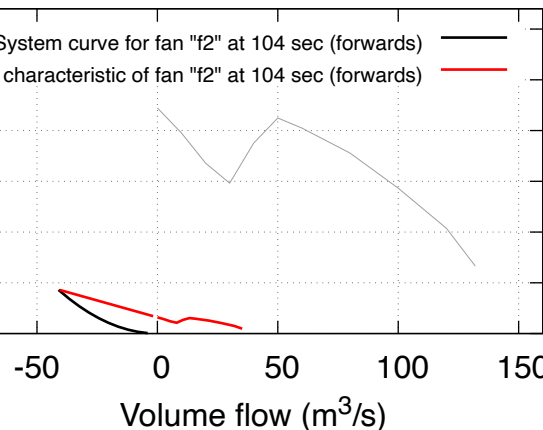
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

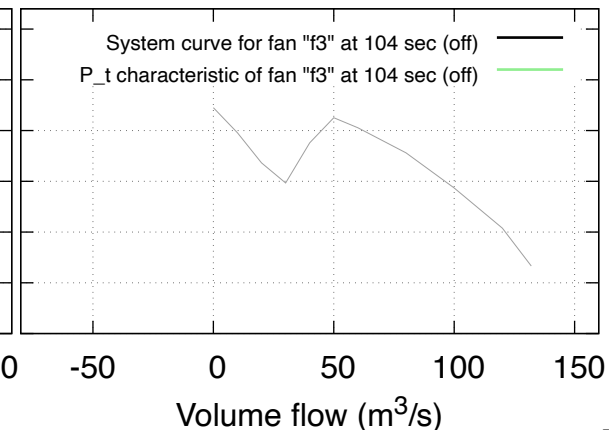
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

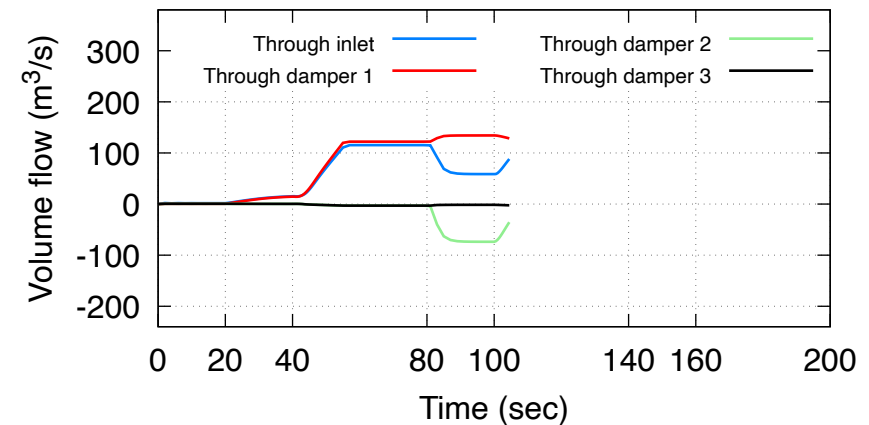
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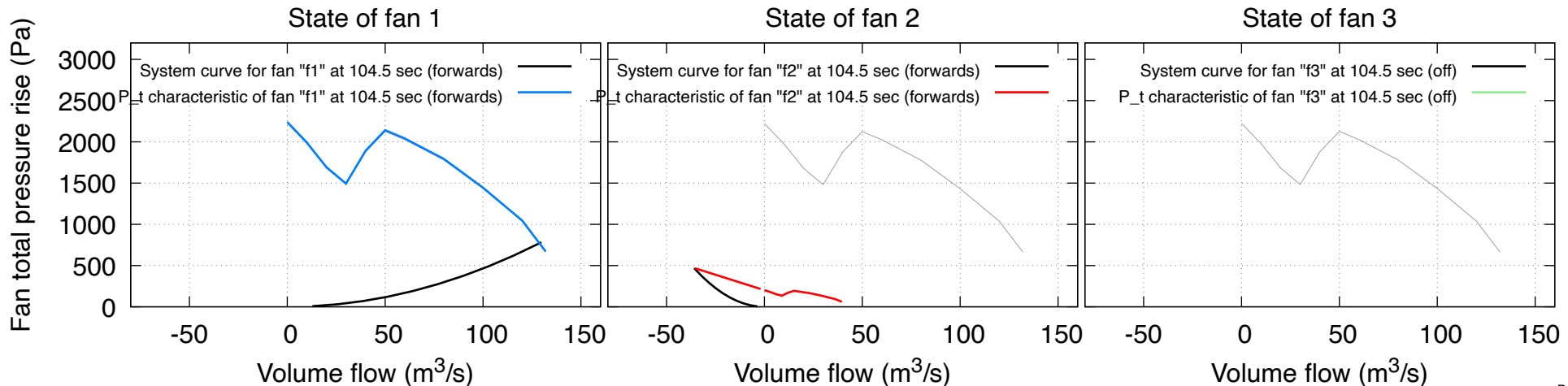
At 40 seconds, fan 1 starts

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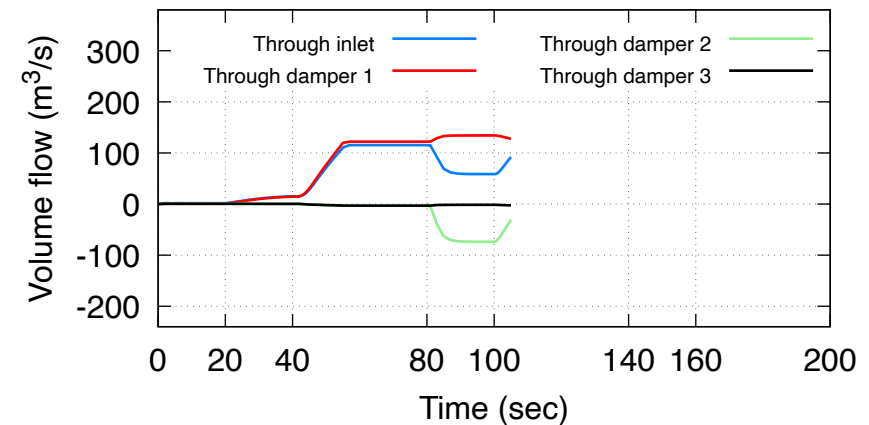
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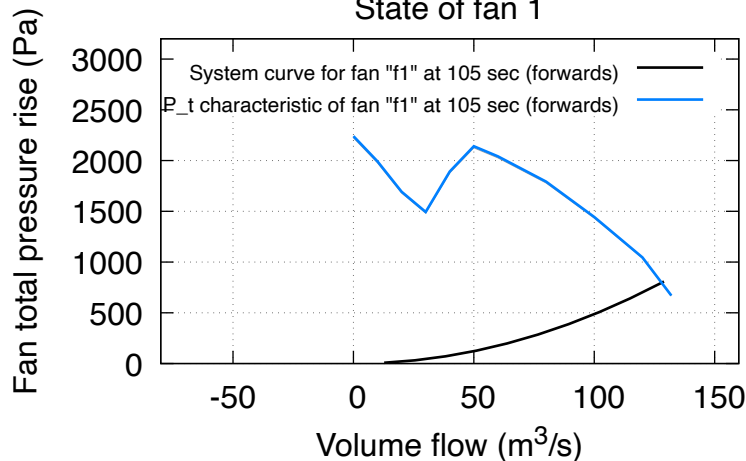
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

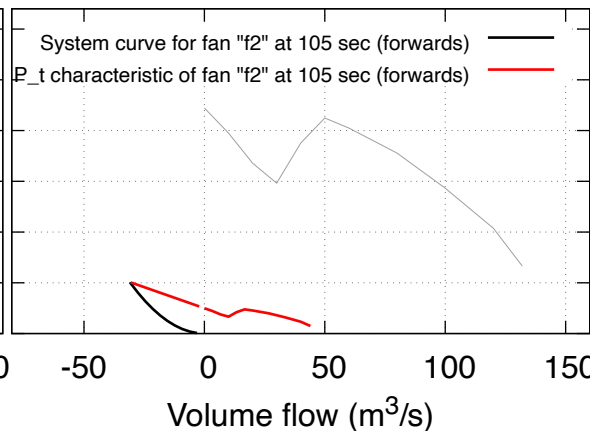
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

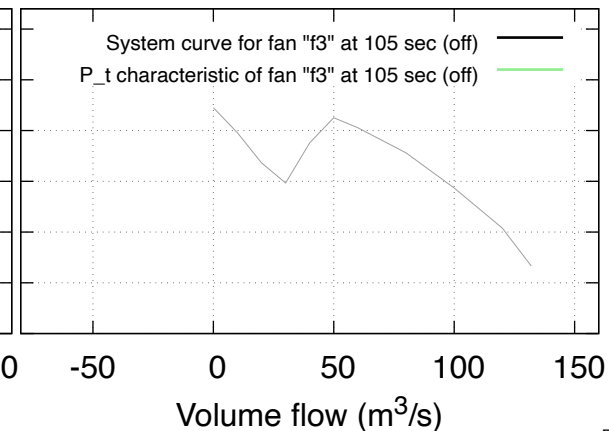
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

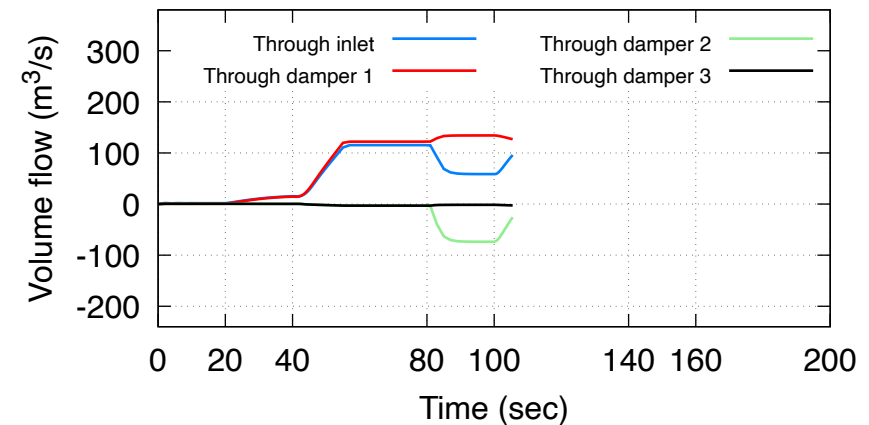
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At 20 seconds, damper 1 opens

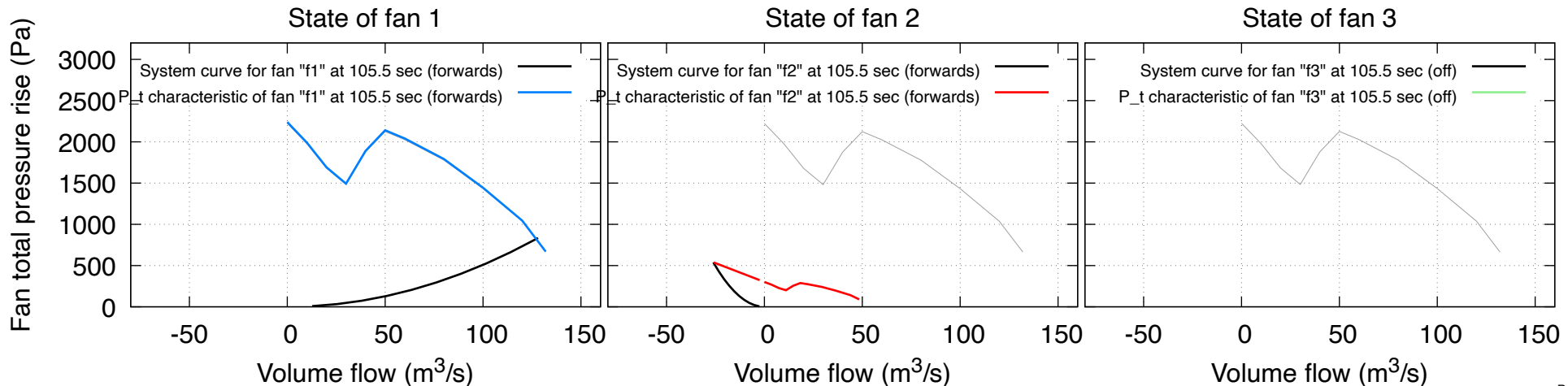
At 40 seconds, fan 1 starts

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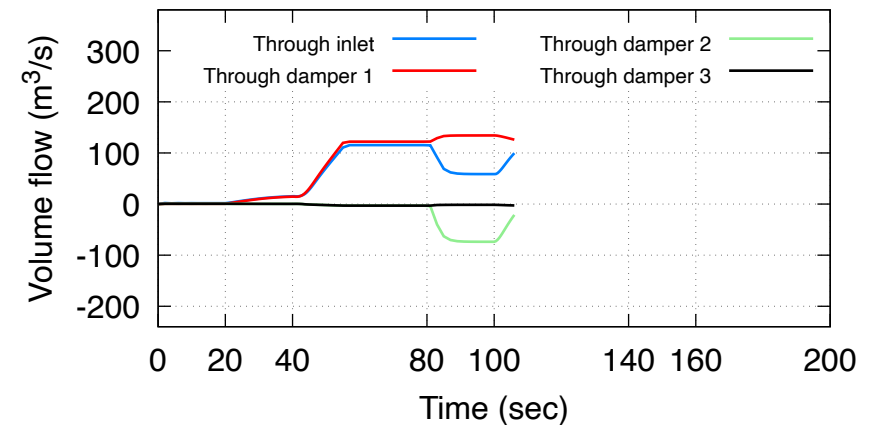
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At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

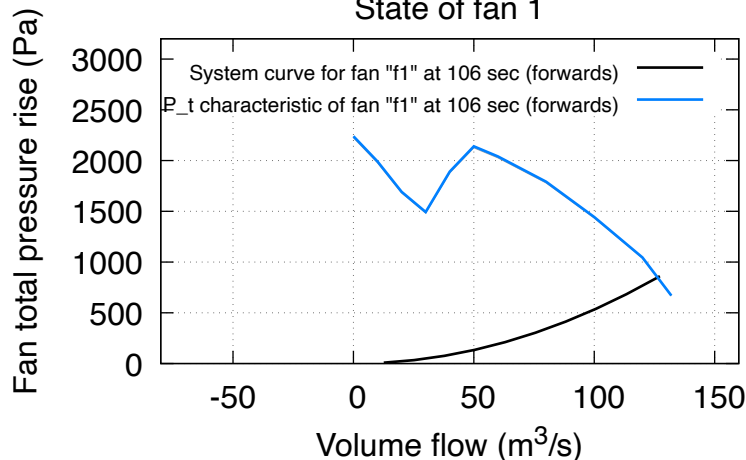
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

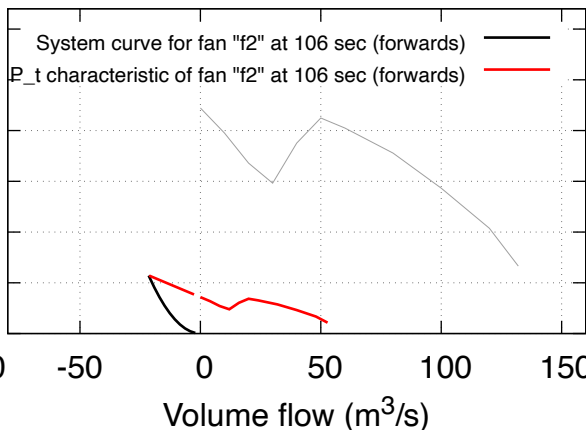
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

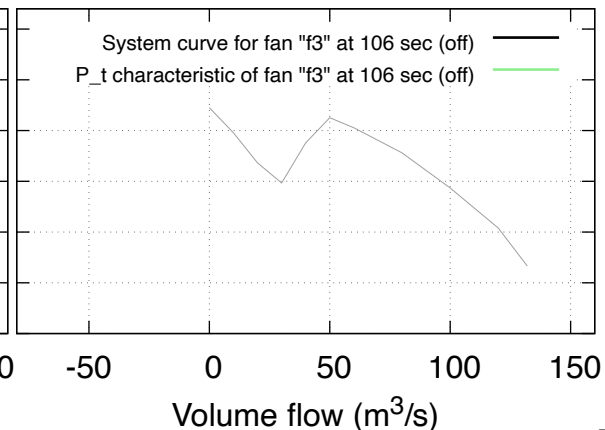
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

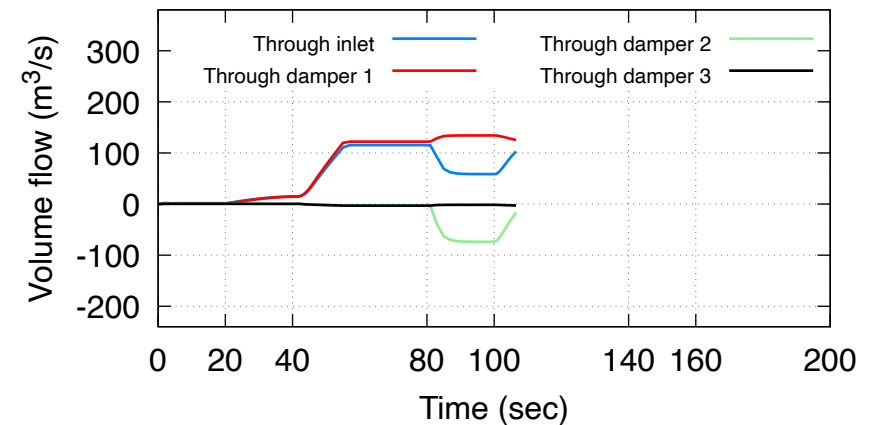
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The fans are started sequentially. Fans 1 and 2 get to suitable parts of their characteristics. Fan 3 can't get out of stall.



Transient volume flows in the system



At 20 seconds, damper 1 opens

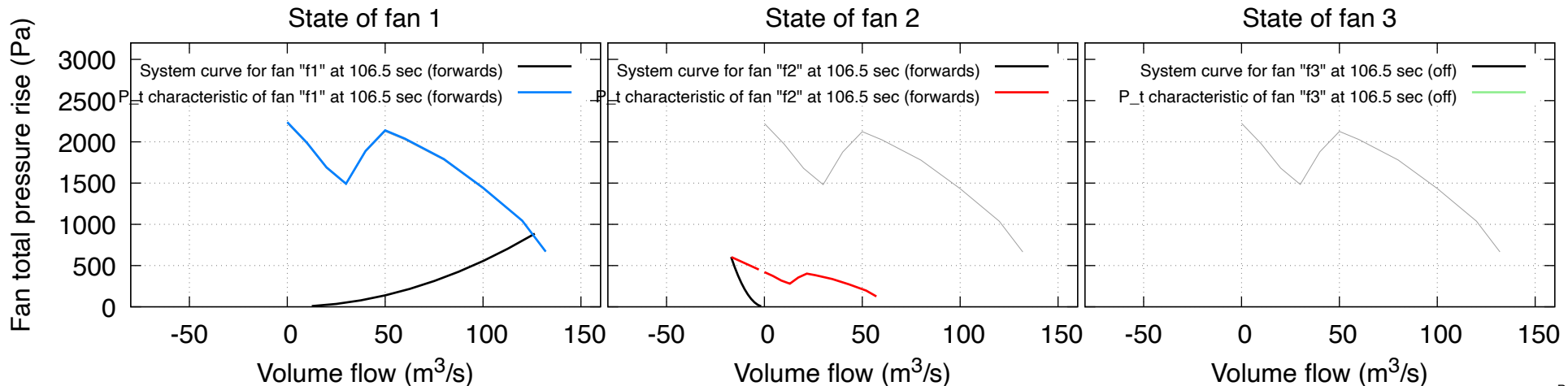
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

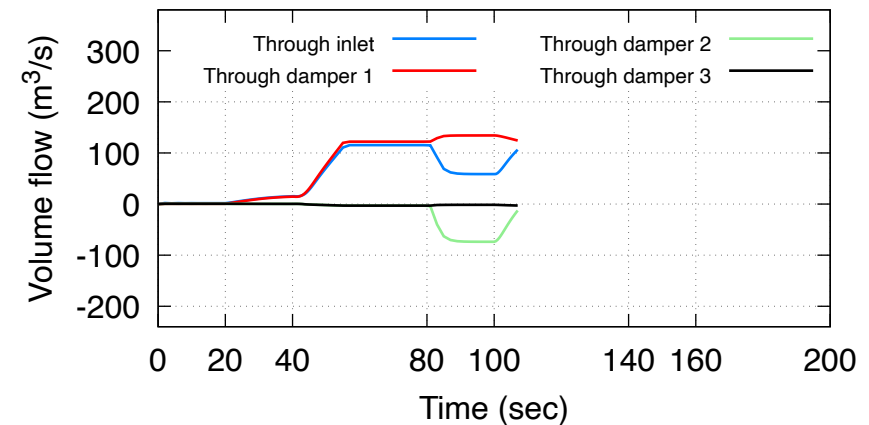
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

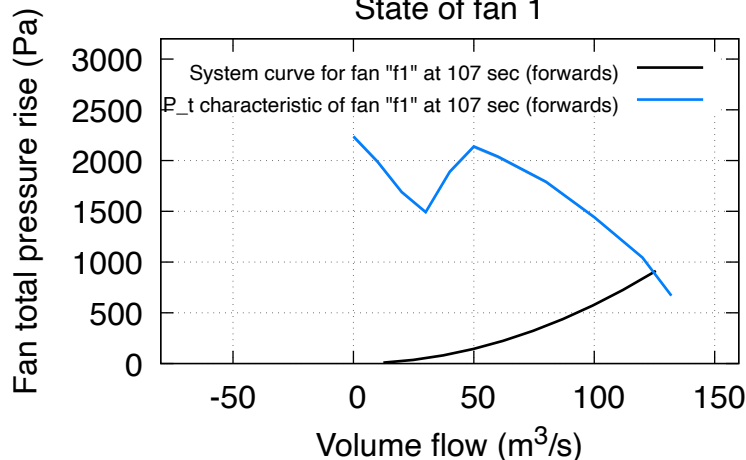
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

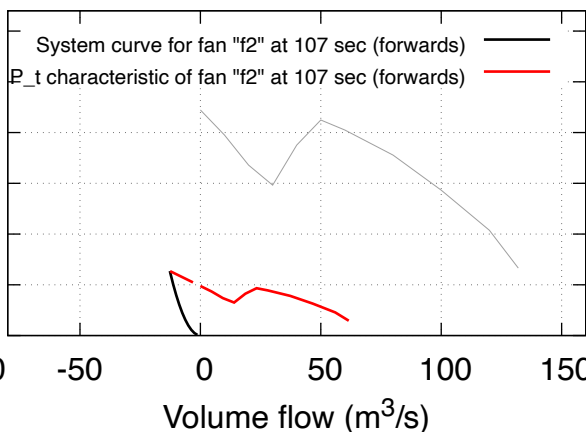
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

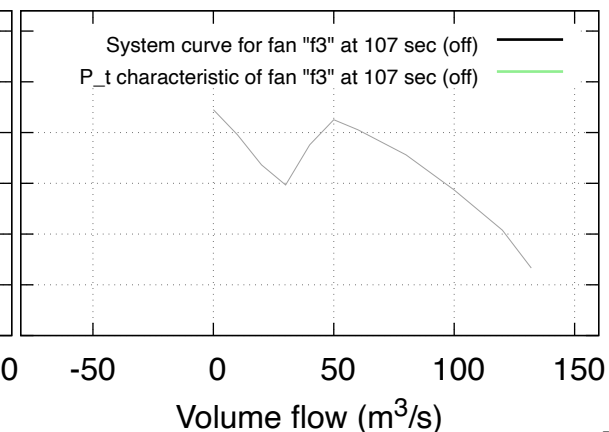
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

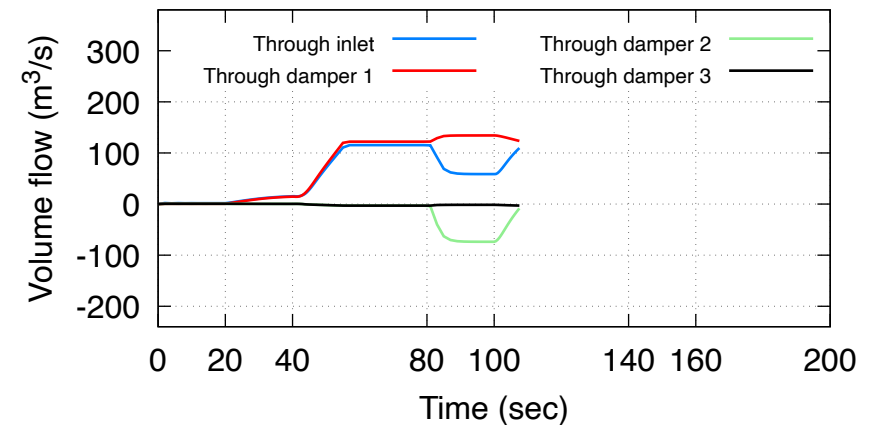
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

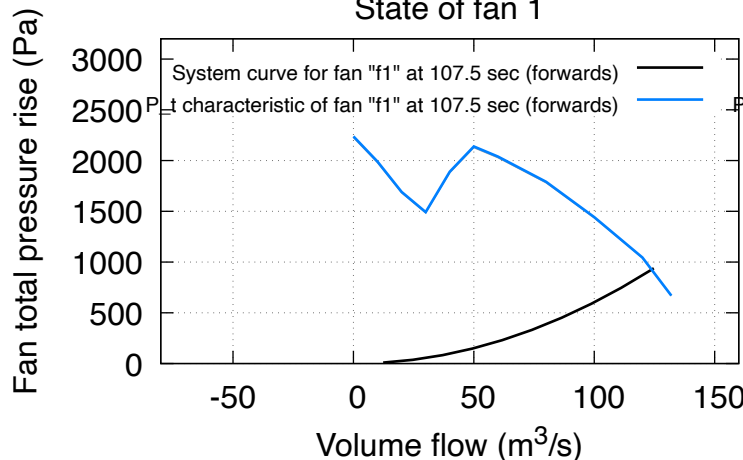
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

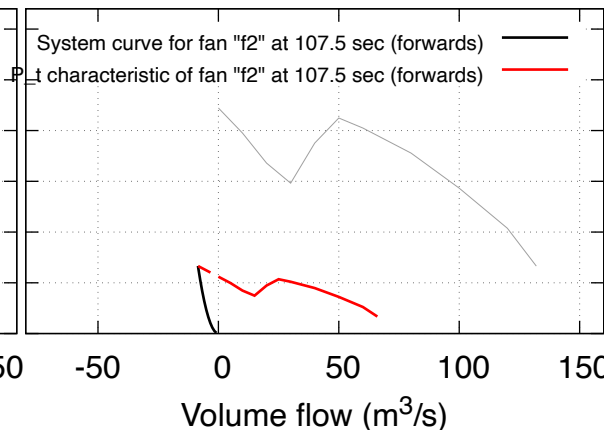
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

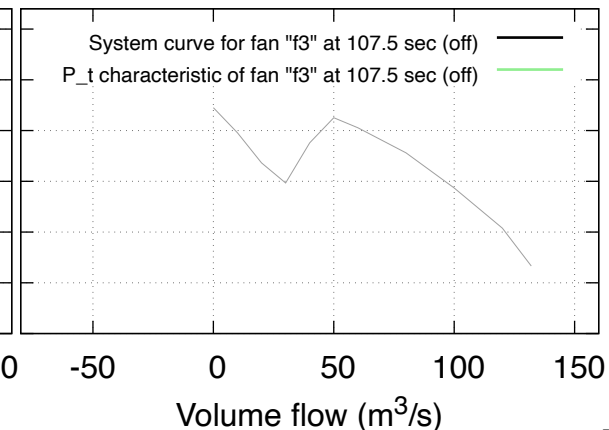
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

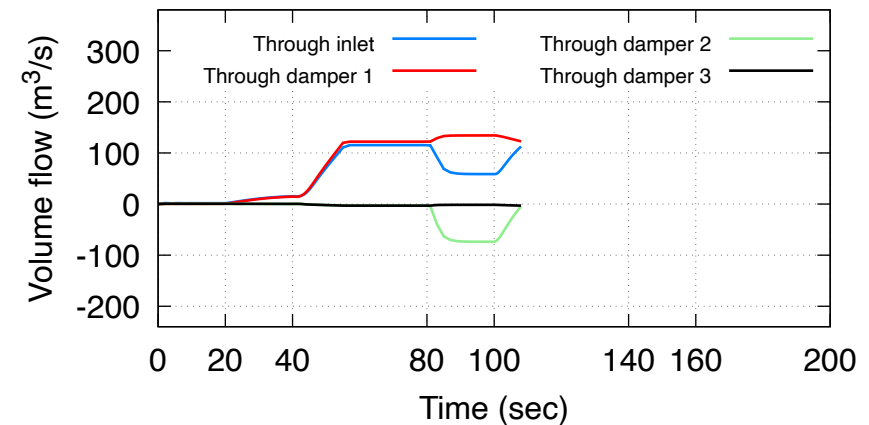
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

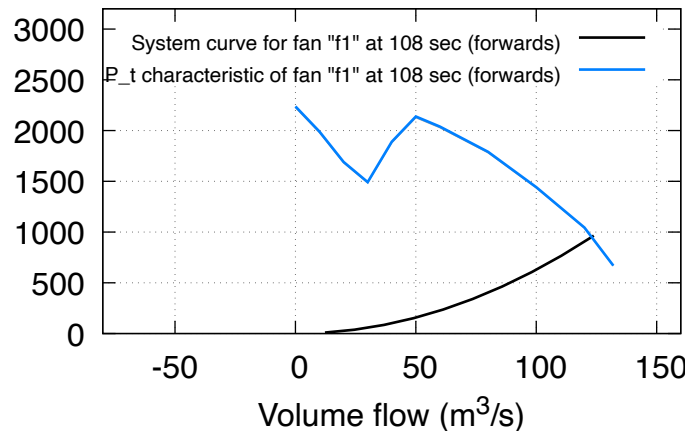
At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

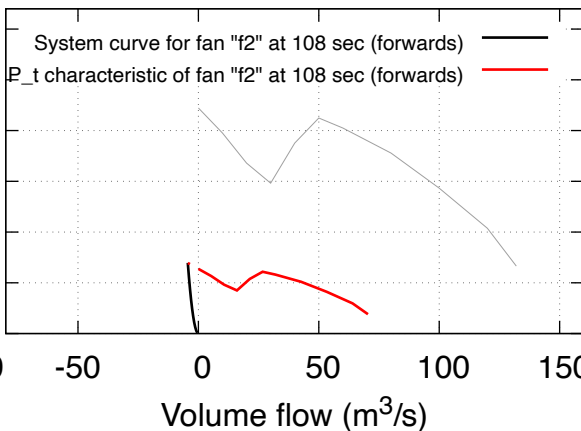
At 160 seconds, fan 3 starts

Fan total pressure rise (Pa)

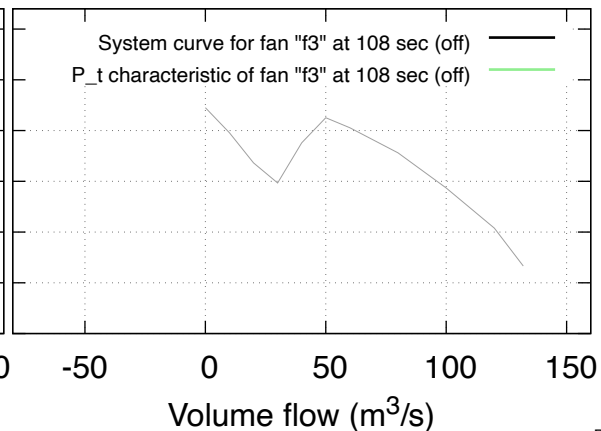
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

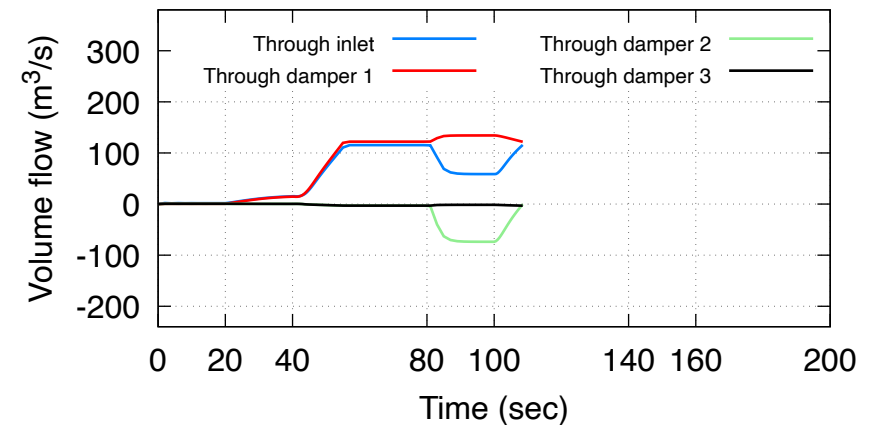
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Transient volume flows in the system



At 20 seconds, damper 1 opens

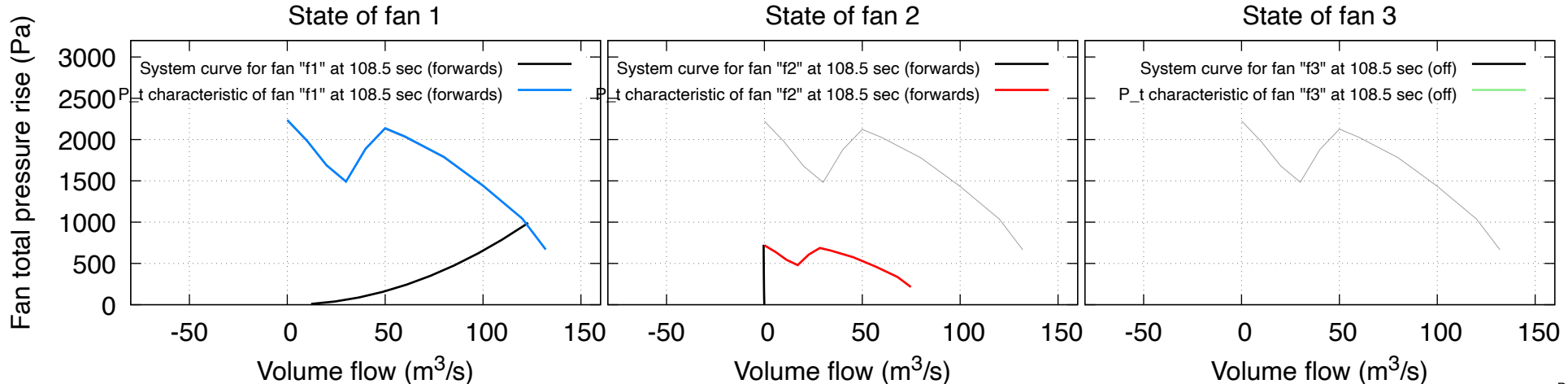
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

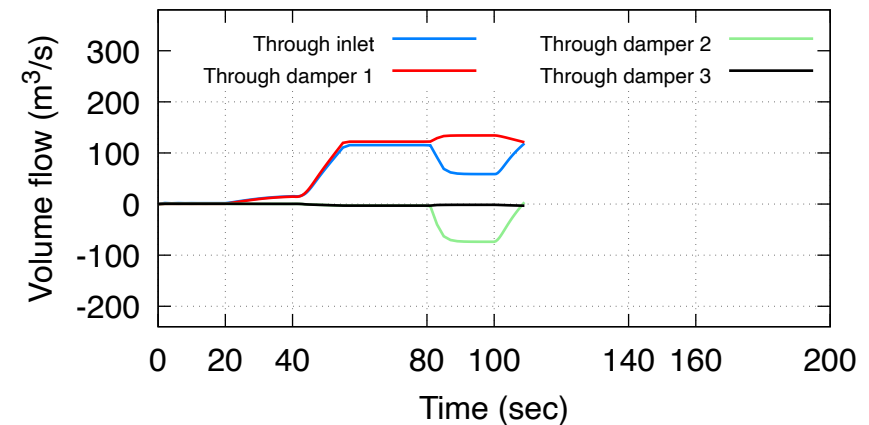
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Transient volume flows in the system



At 20 seconds, damper 1 opens

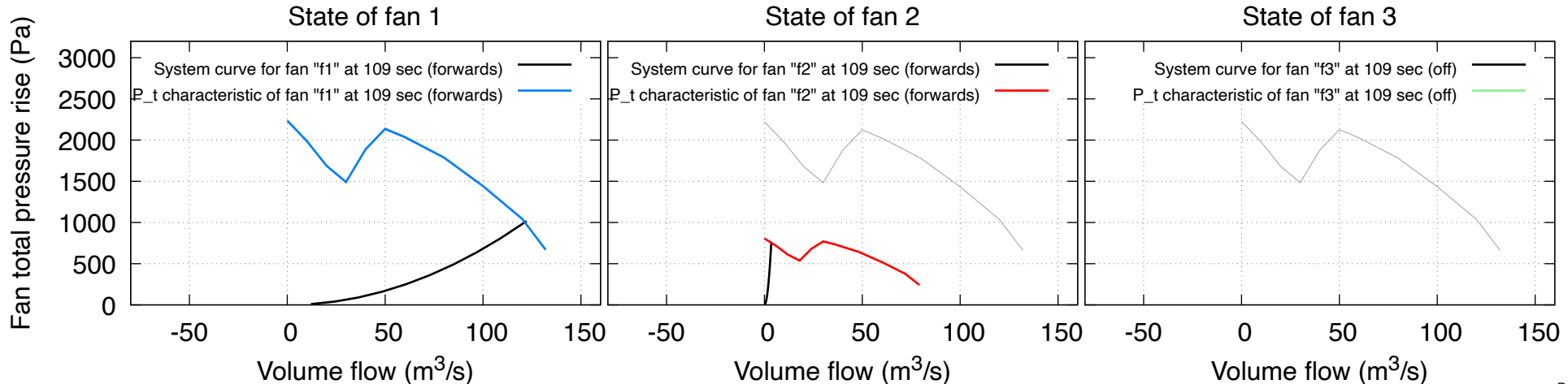
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

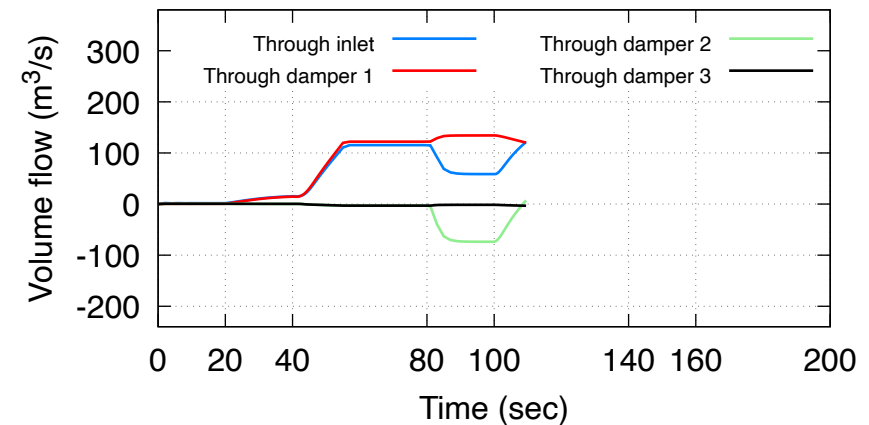
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Transient volume flows in the system



At 20 seconds, damper 1 opens

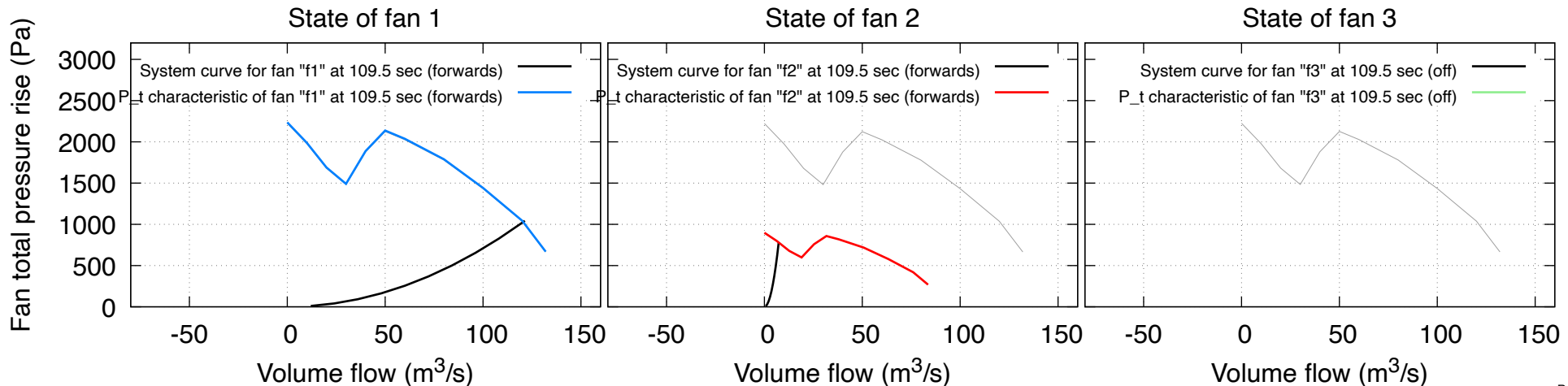
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

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At 160 seconds, fan 3 starts



How not to run fans in parallel

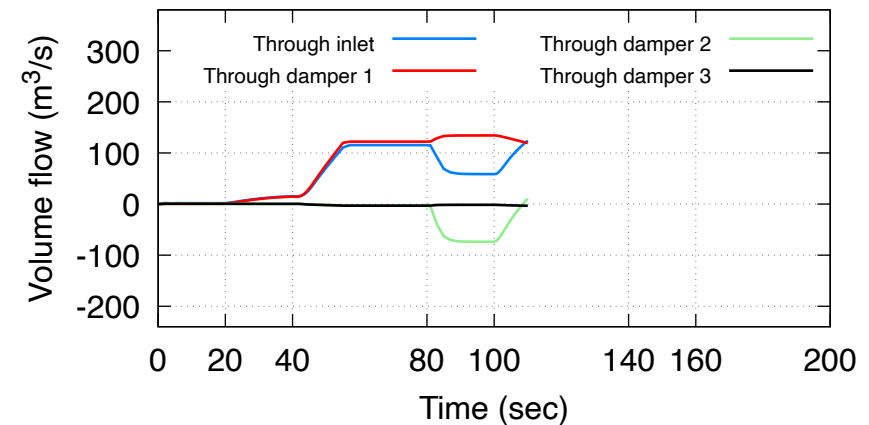
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Transient volume flows in the system



At 20 seconds, damper 1 opens

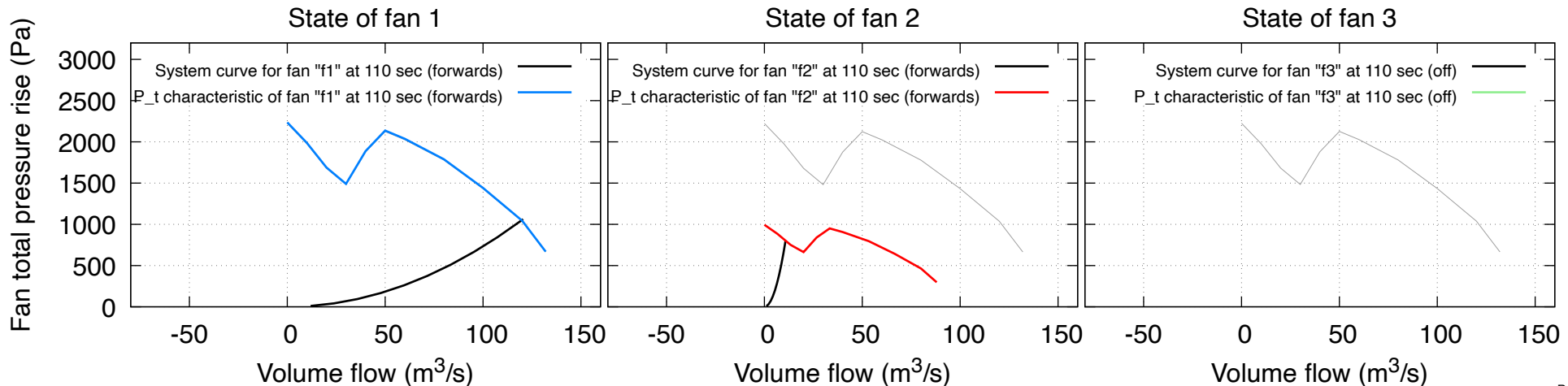
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

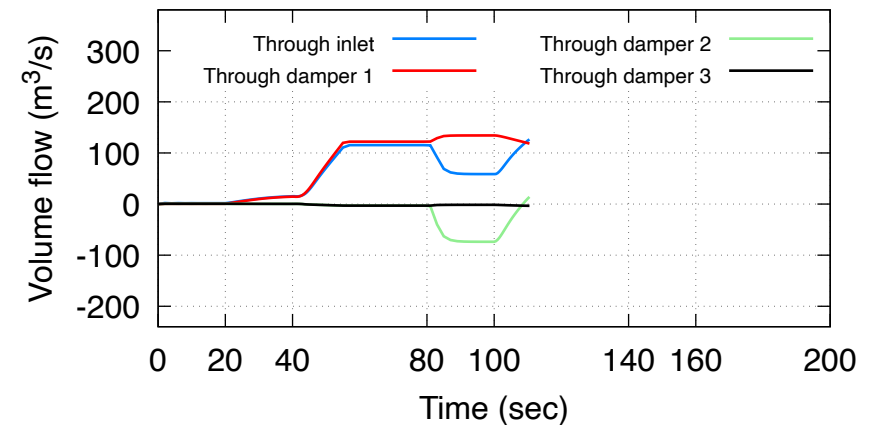
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Transient volume flows in the system



At 20 seconds, damper 1 opens

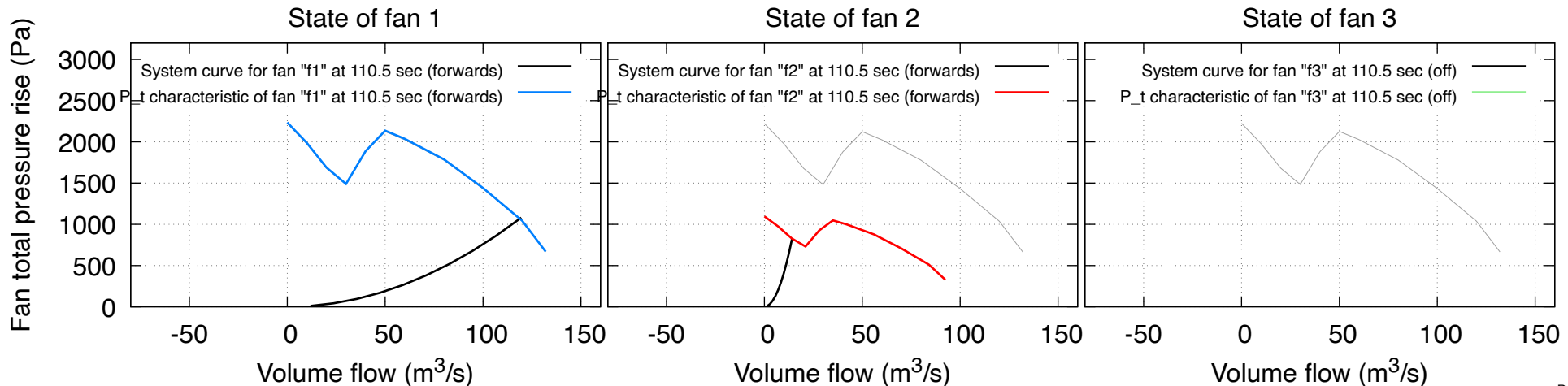
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

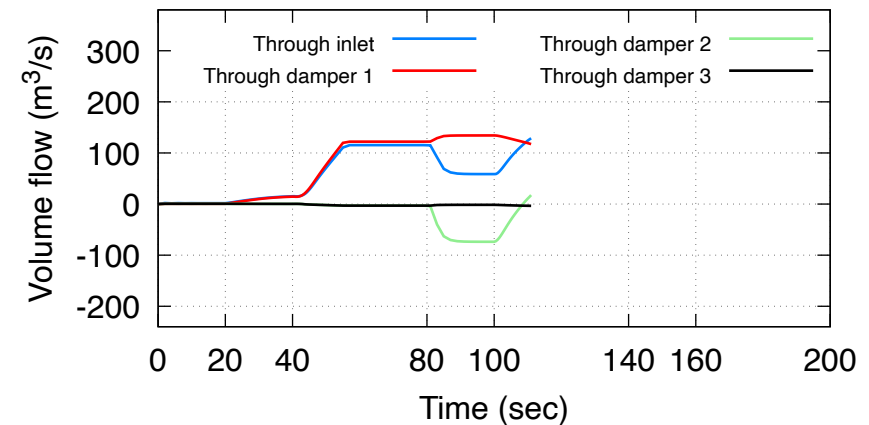
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Transient volume flows in the system



At 20 seconds, damper 1 opens

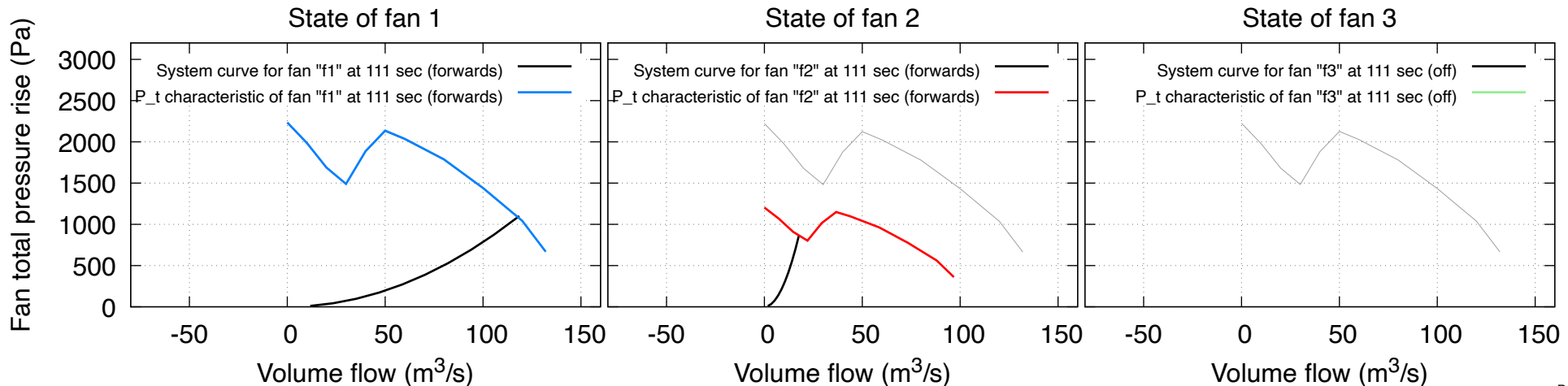
At 40 seconds, fan 1 starts

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How not to run fans in parallel

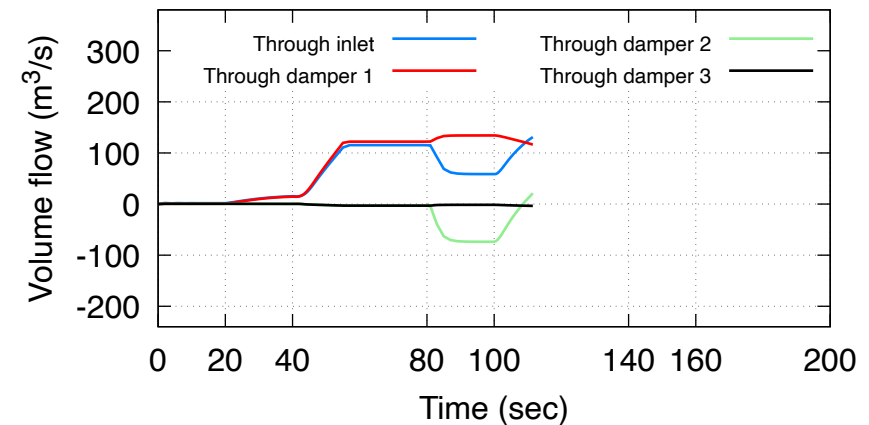
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Transient volume flows in the system



At 20 seconds, damper 1 opens

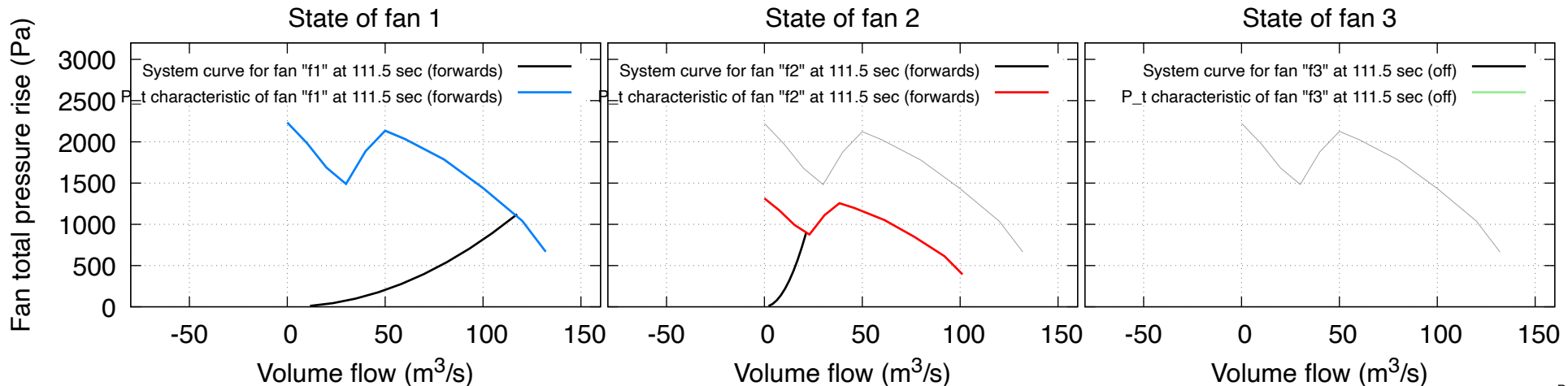
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

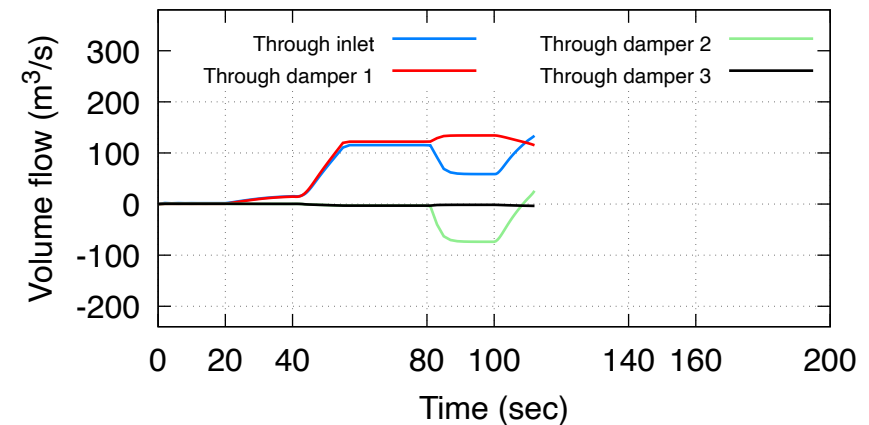
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

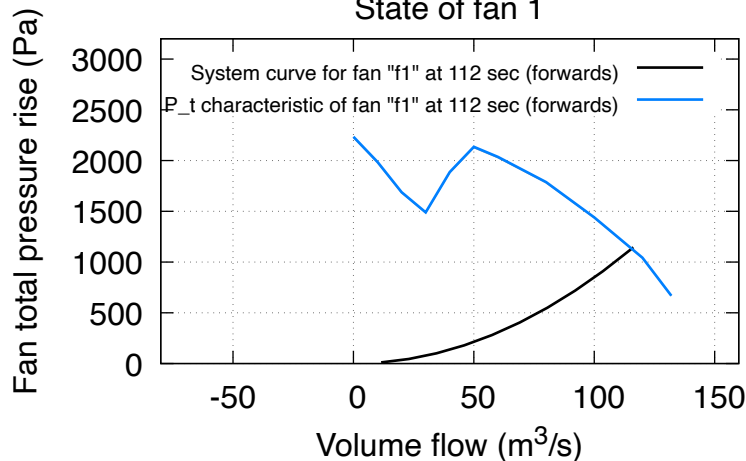
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

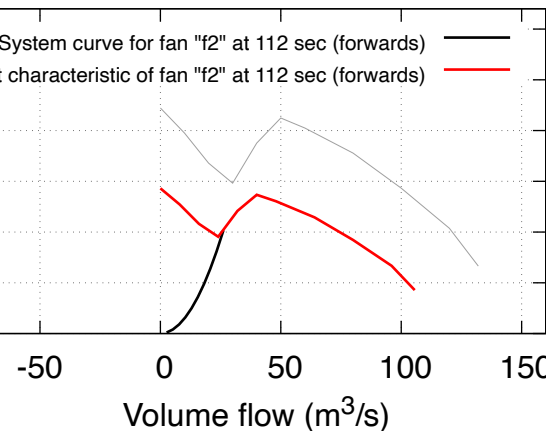
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

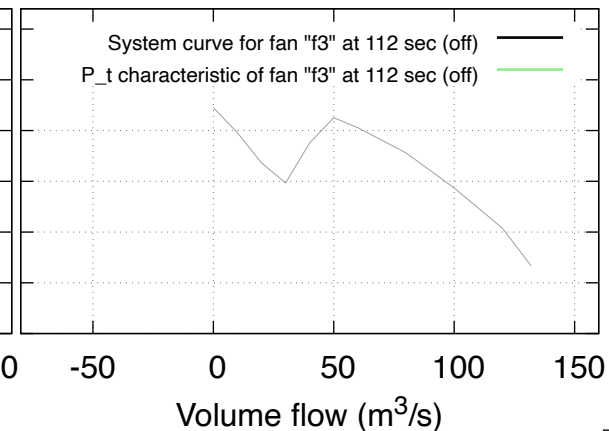
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

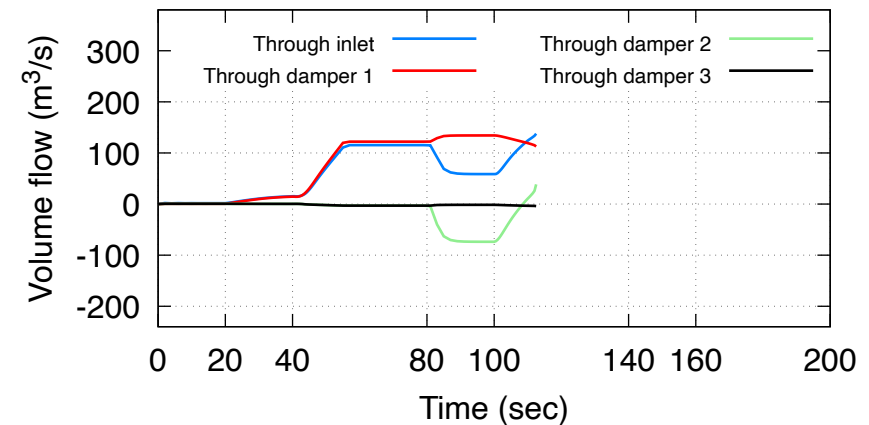
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At 20 seconds, damper 1 opens

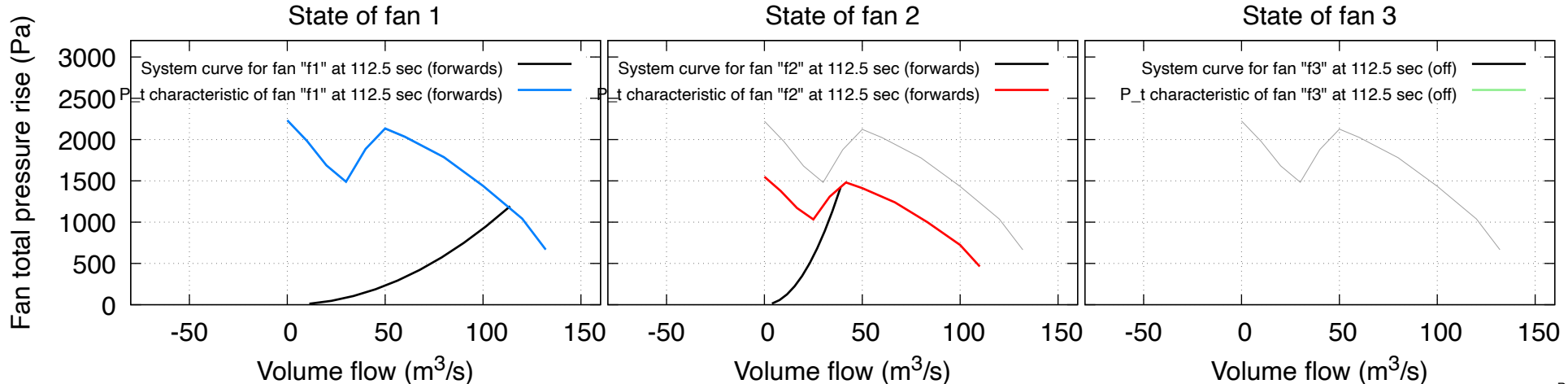
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



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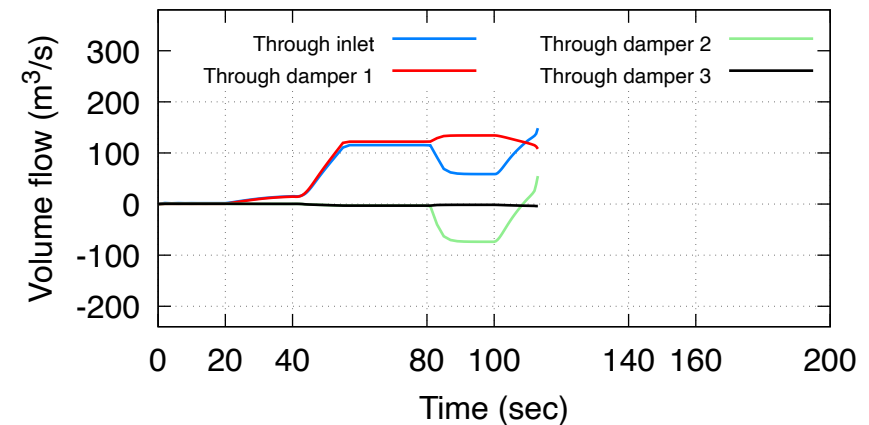
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At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

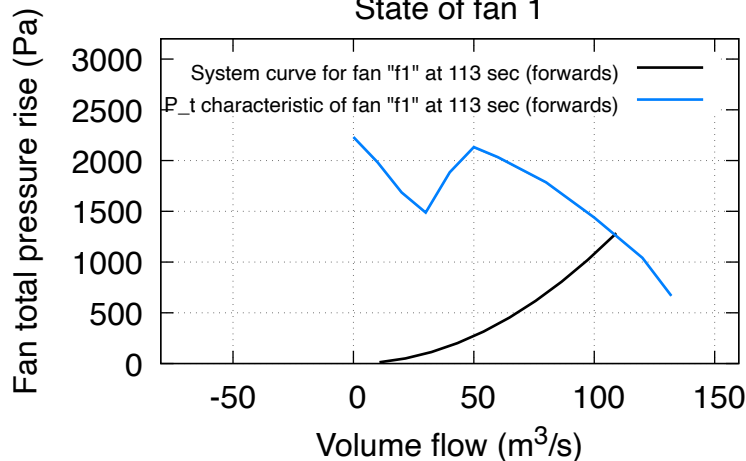
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

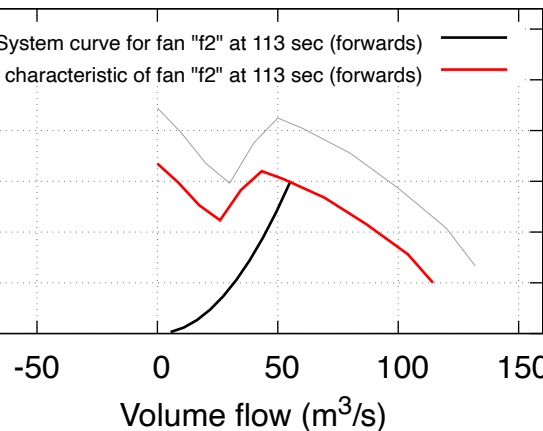
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

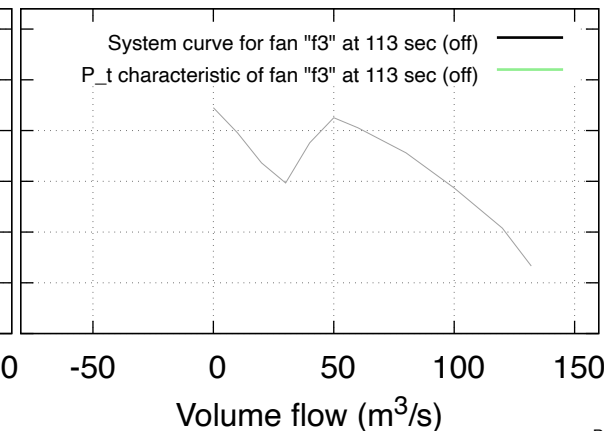
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

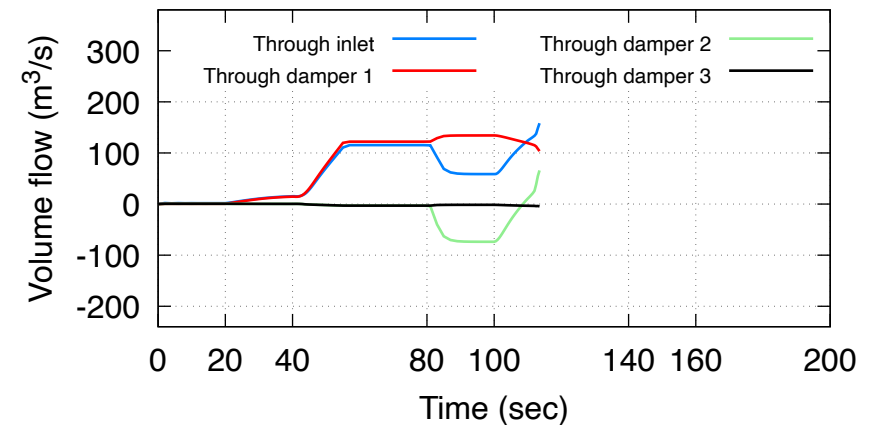
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At 20 seconds, damper 1 opens

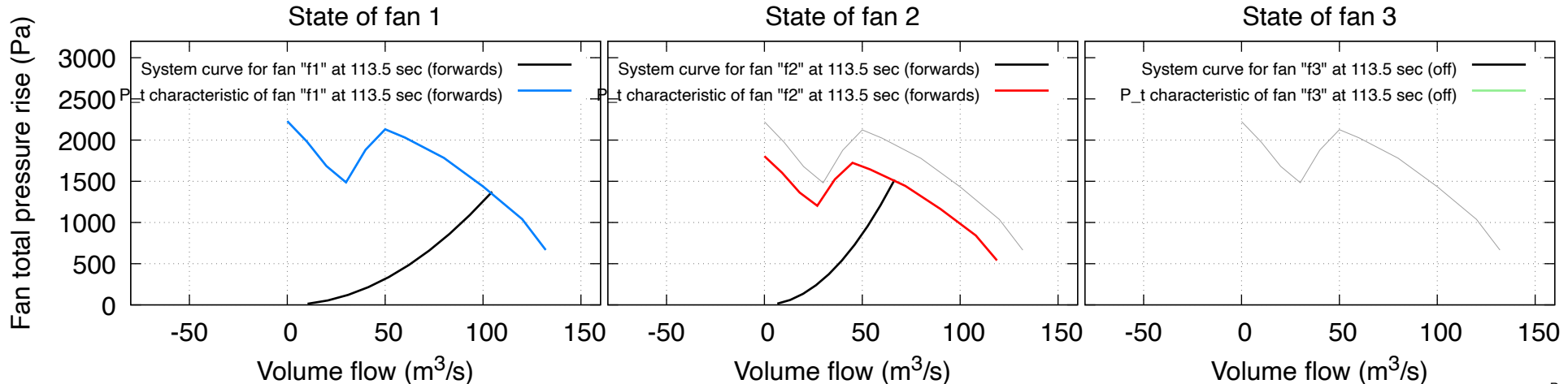
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

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How not to run fans in parallel

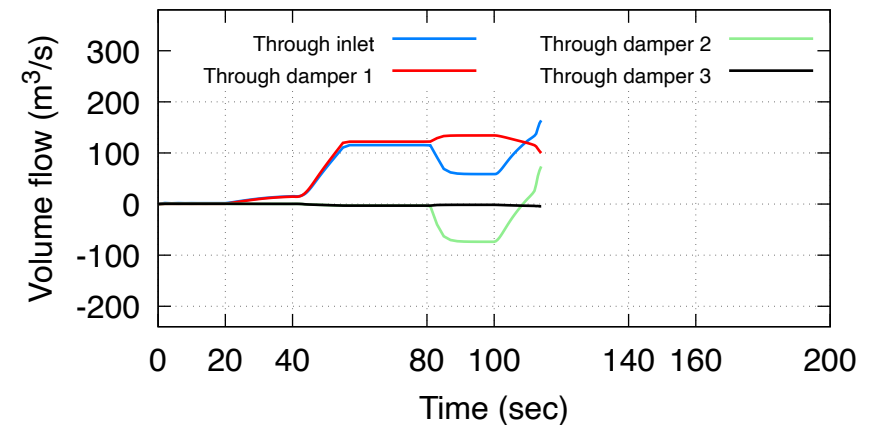
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At 20 seconds, damper 1 opens

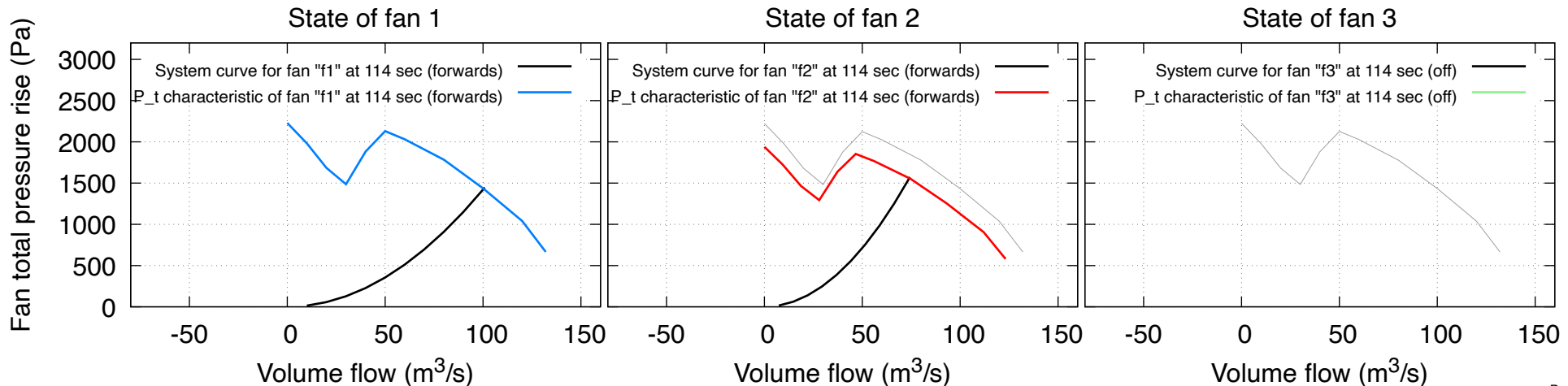
At 40 seconds, fan 1 starts

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At 160 seconds, fan 3 starts



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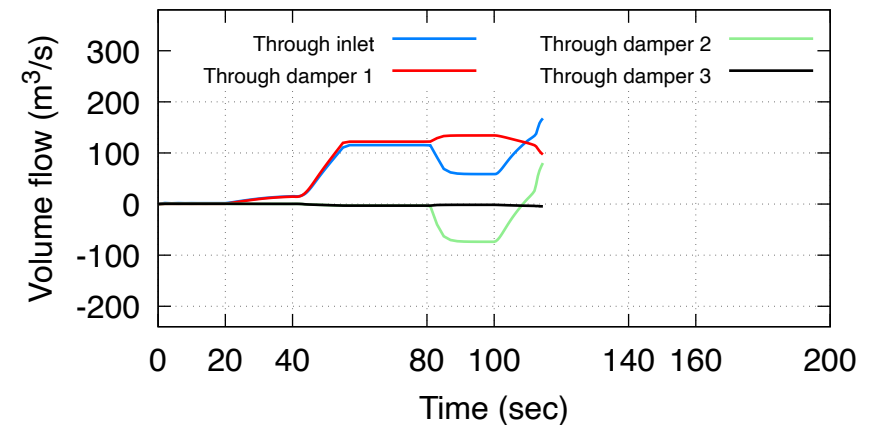
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At 20 seconds, damper 1 opens

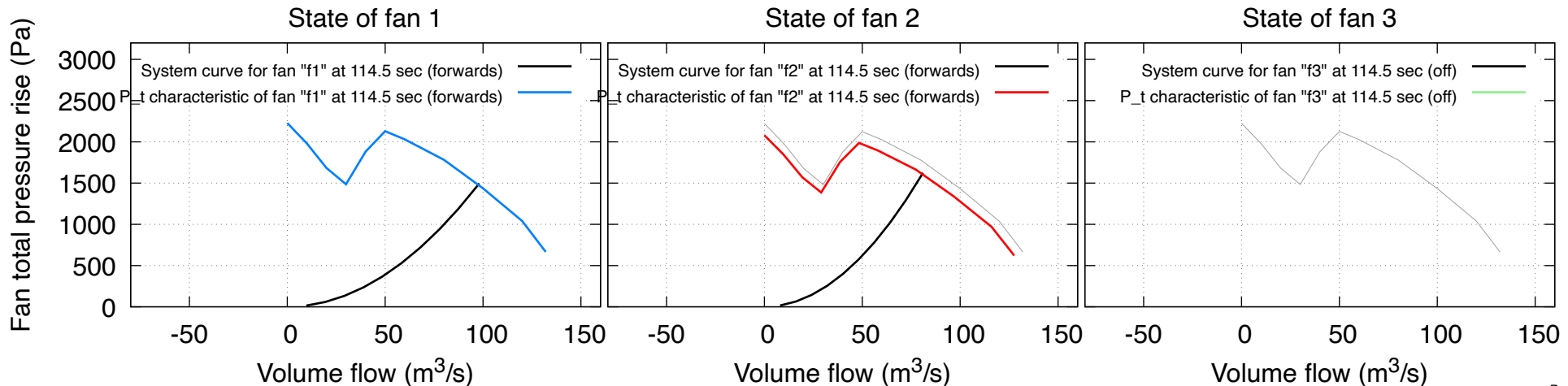
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

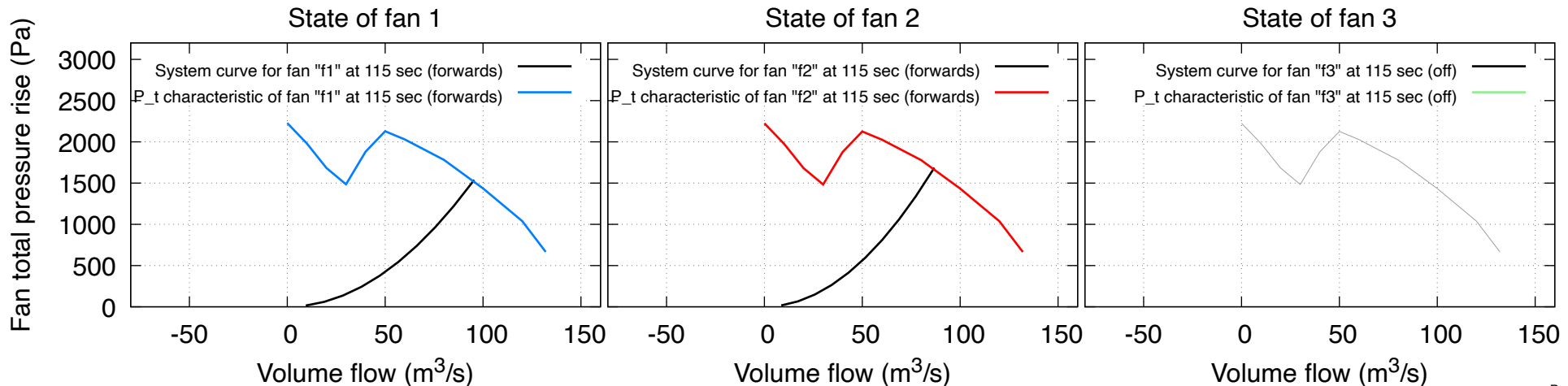
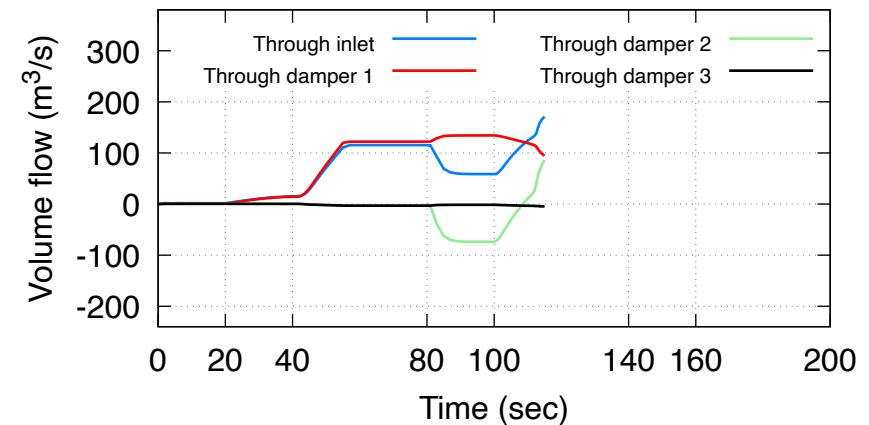
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Transient volume flows in the system



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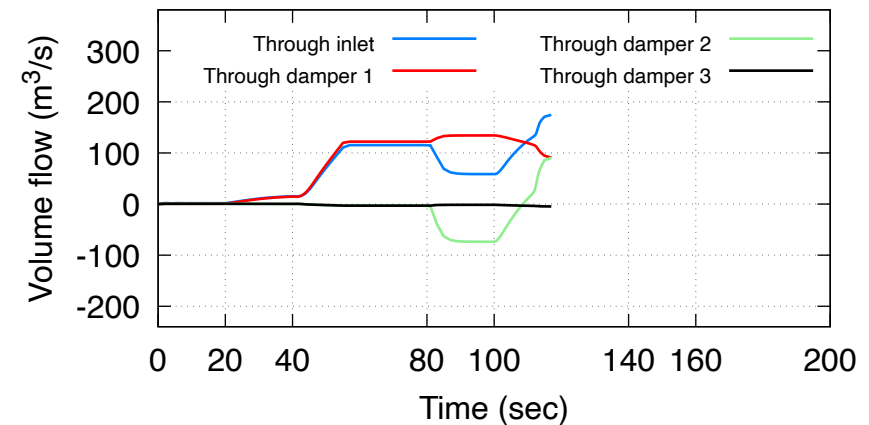
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At 20 seconds, damper 1 opens

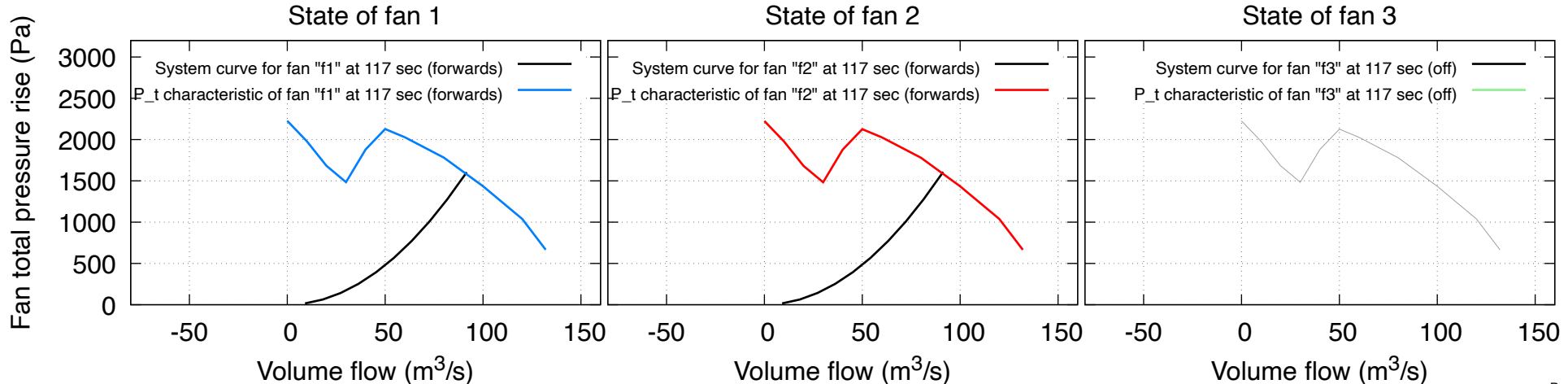
At 40 seconds, fan 1 starts

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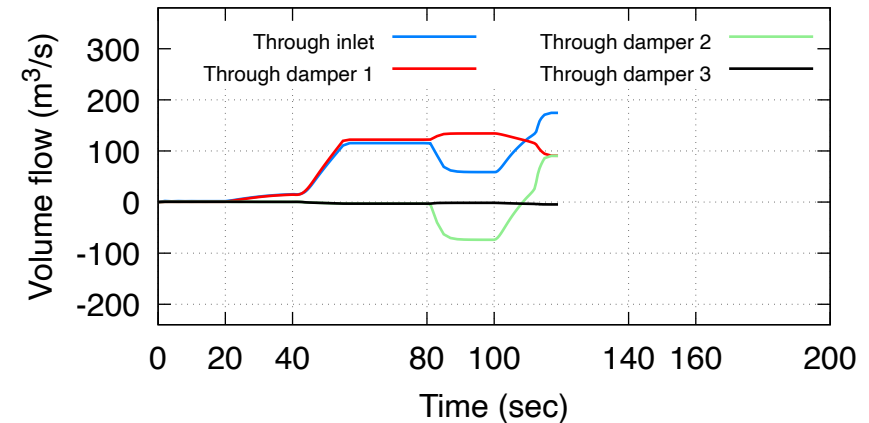
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At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

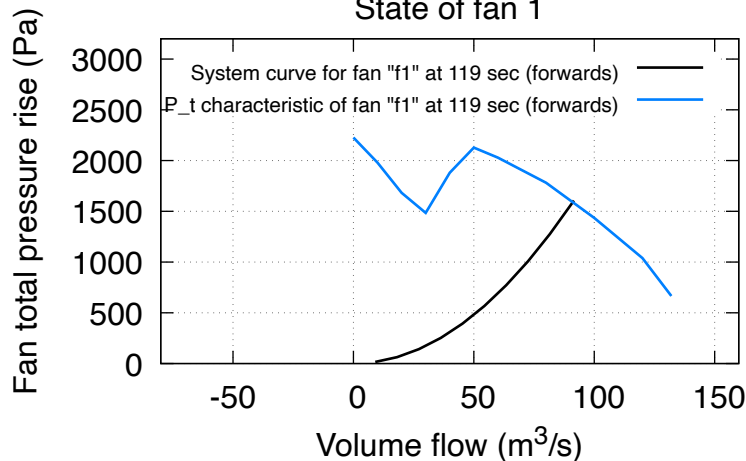
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

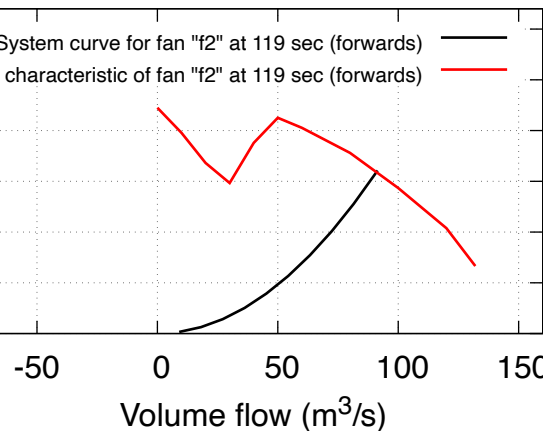
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

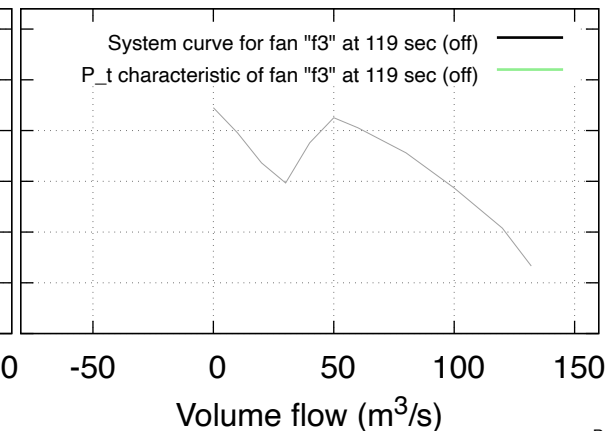
State of fan 1



State of fan 2



State of fan 3



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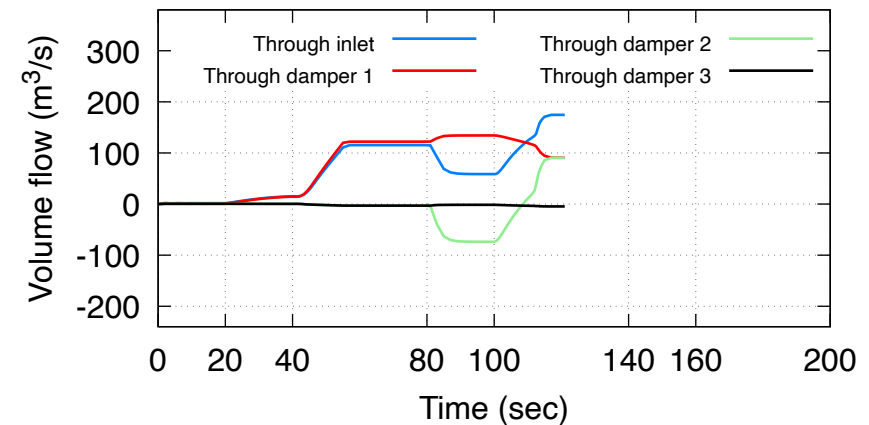
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Transient volume flows in the system



At 20 seconds, damper 1 opens

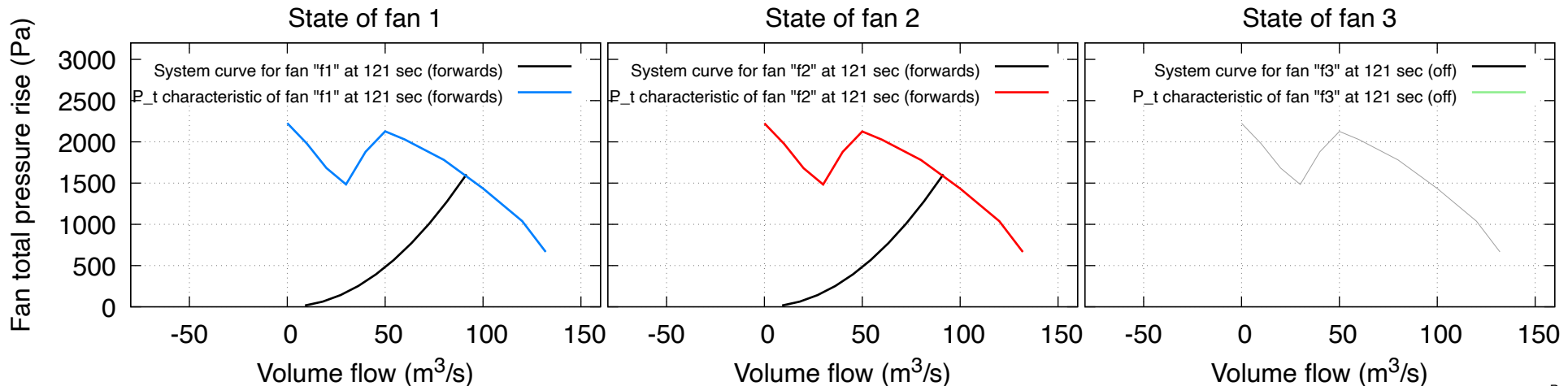
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

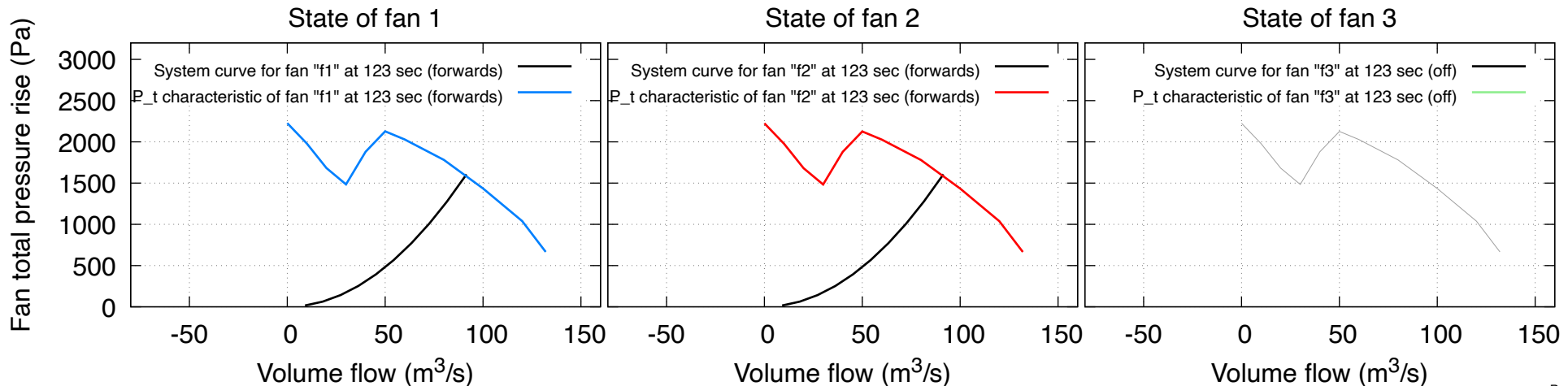
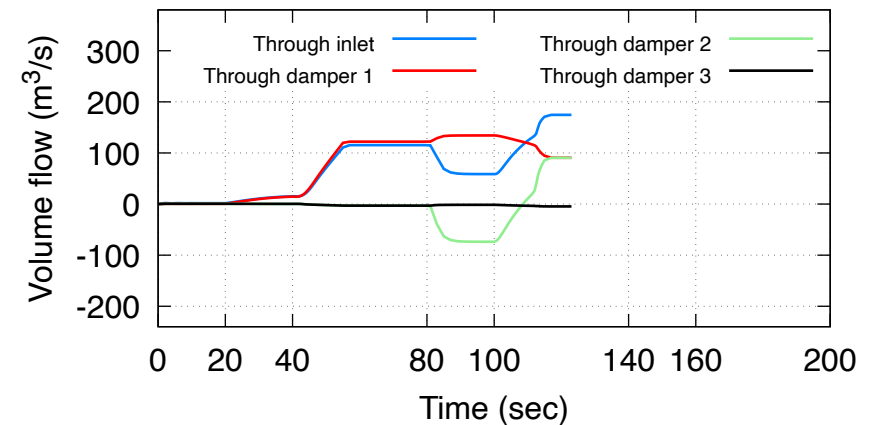
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Transient volume flows in the system



How not to run fans in parallel

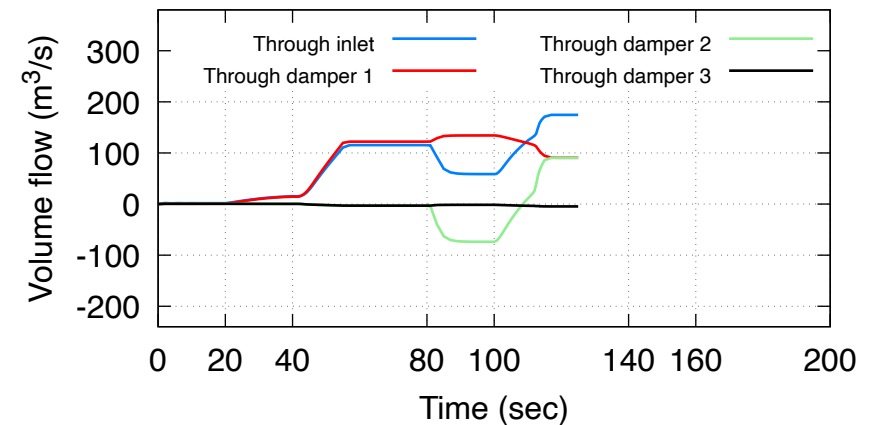
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

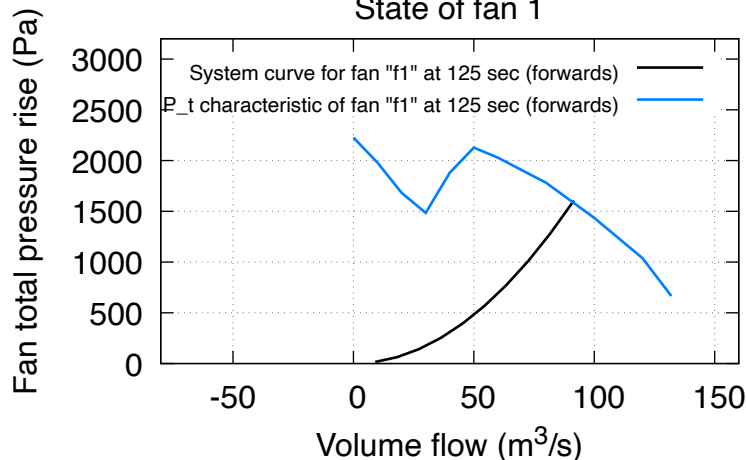
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

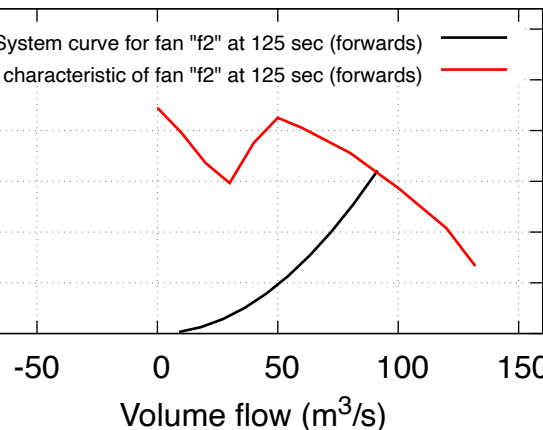
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

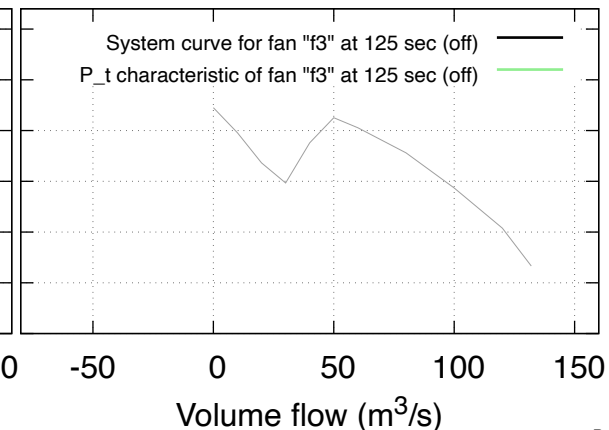
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

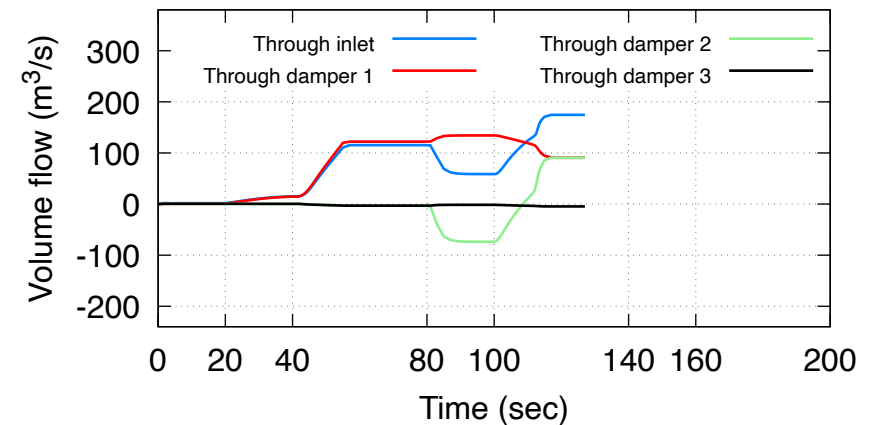
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Transient volume flows in the system



At 20 seconds, damper 1 opens

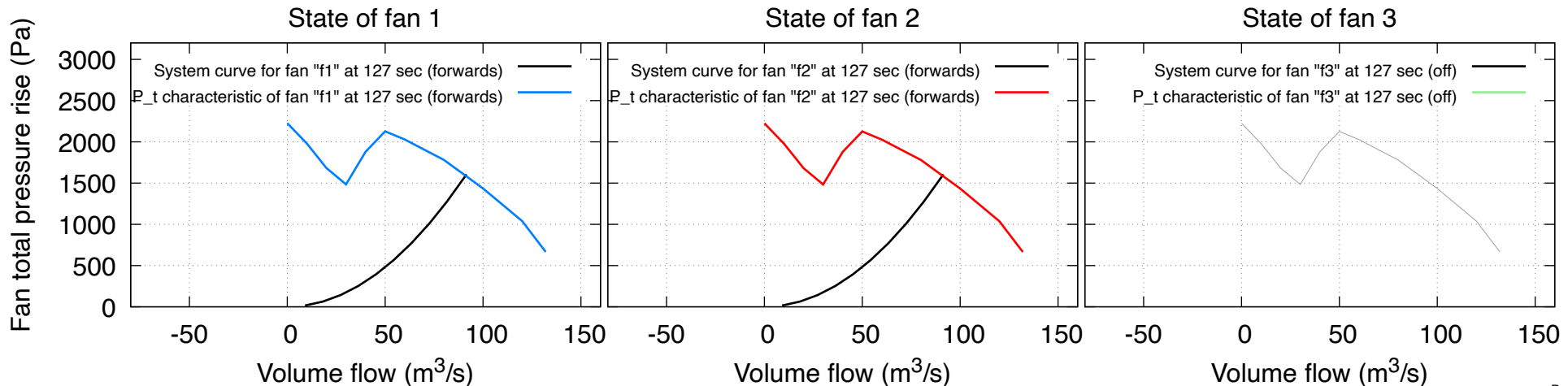
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

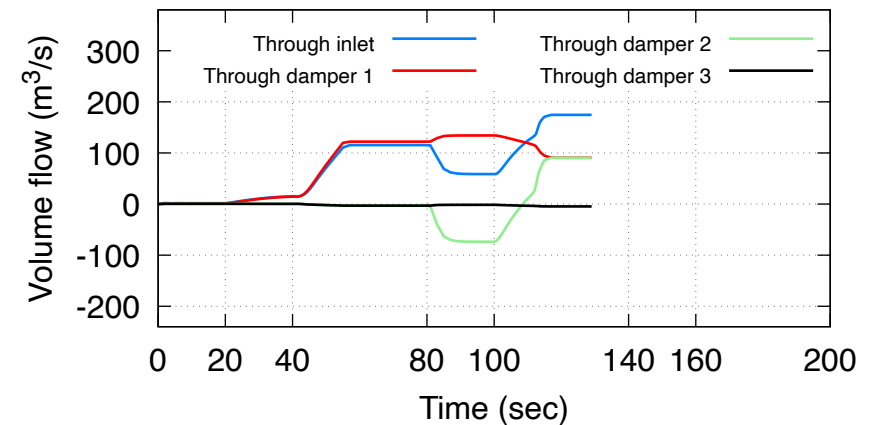
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Transient volume flows in the system



At 20 seconds, damper 1 opens

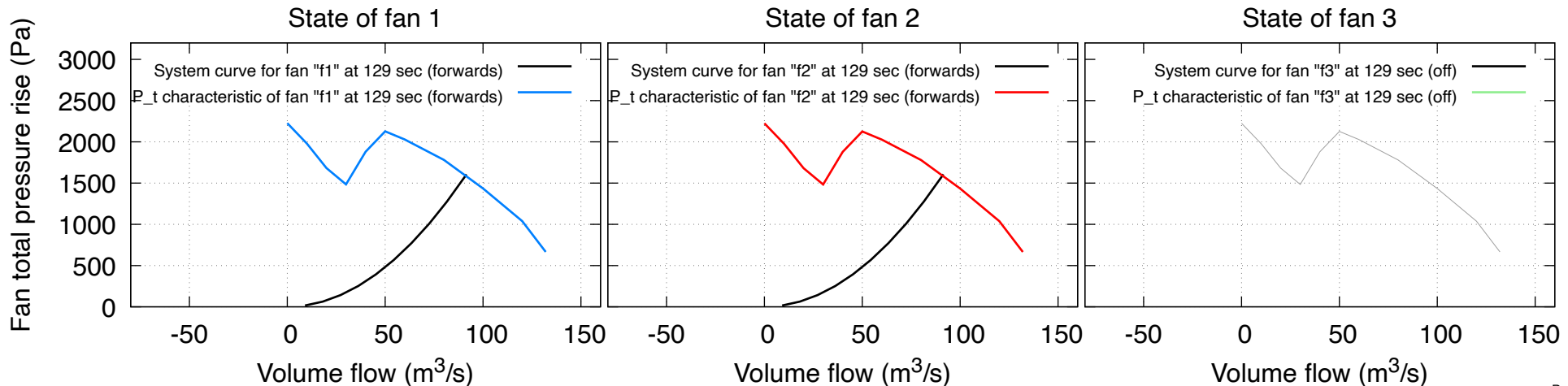
At 40 seconds, fan 1 starts

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How not to run fans in parallel

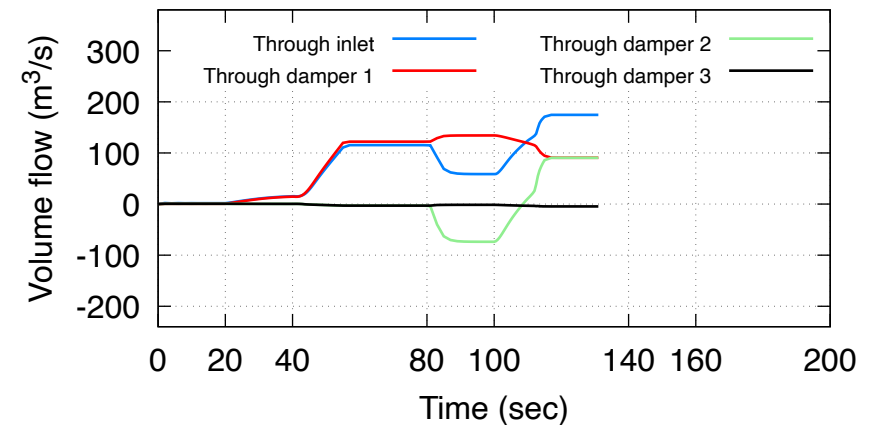
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Transient volume flows in the system



At 20 seconds, damper 1 opens

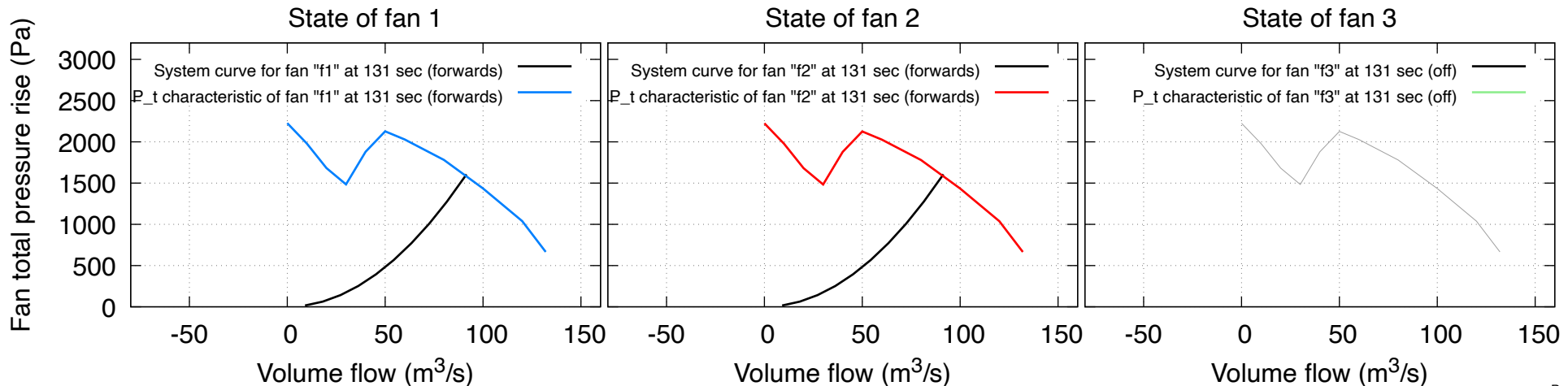
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

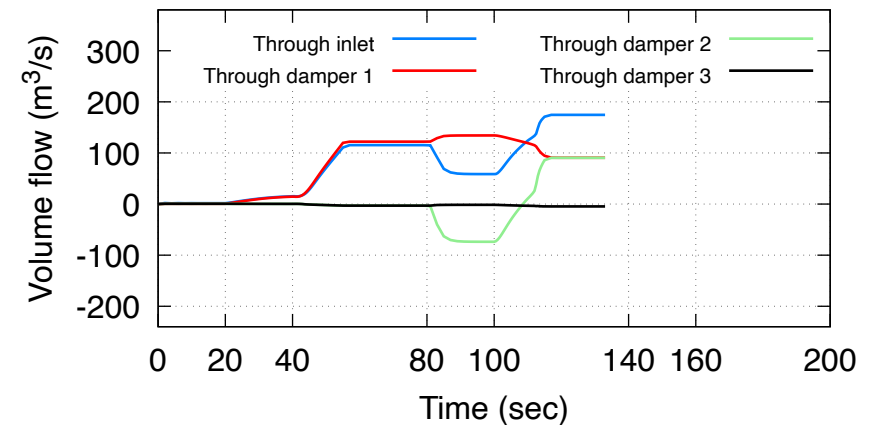
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Transient volume flows in the system



At 20 seconds, damper 1 opens

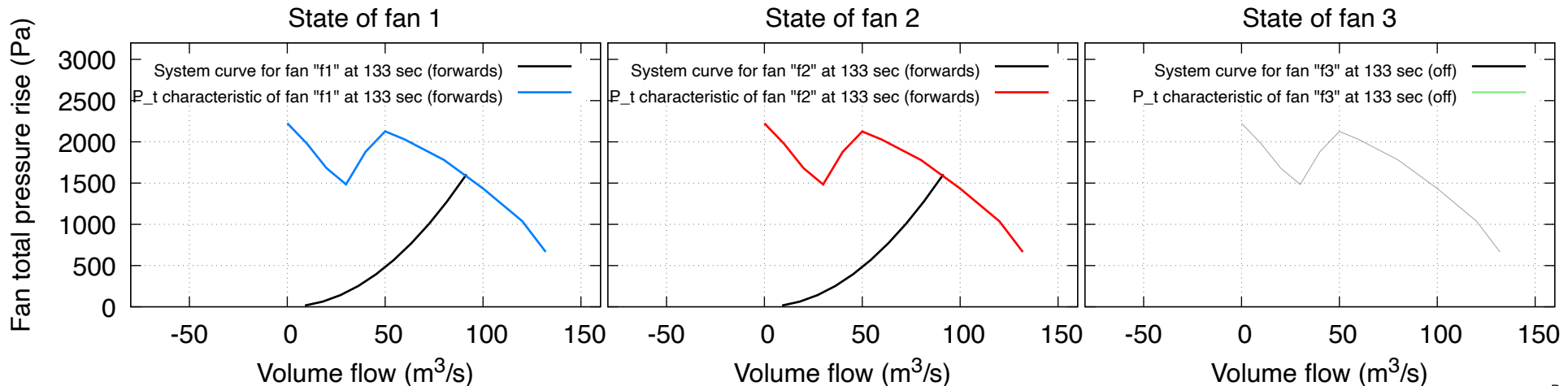
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

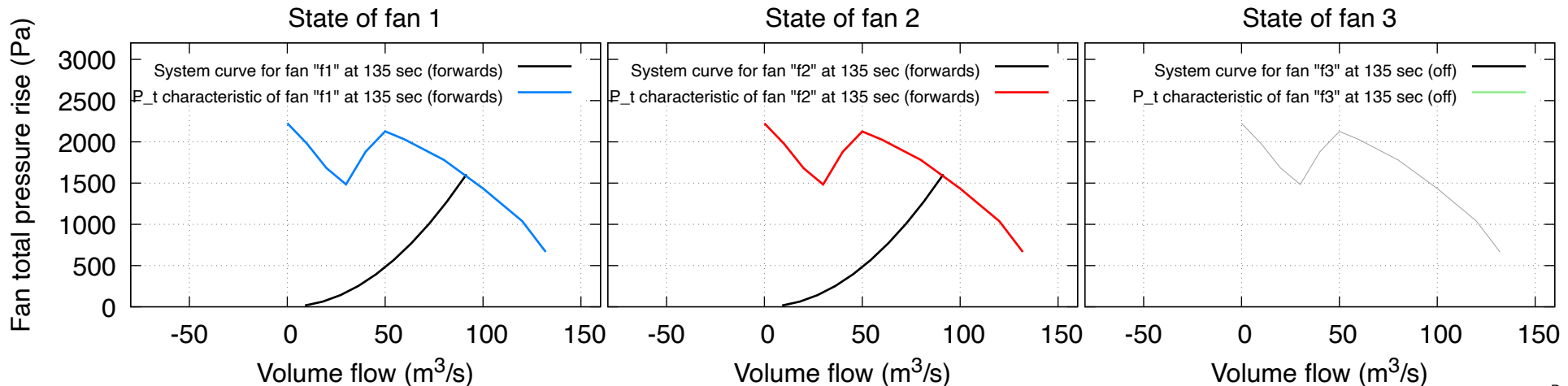
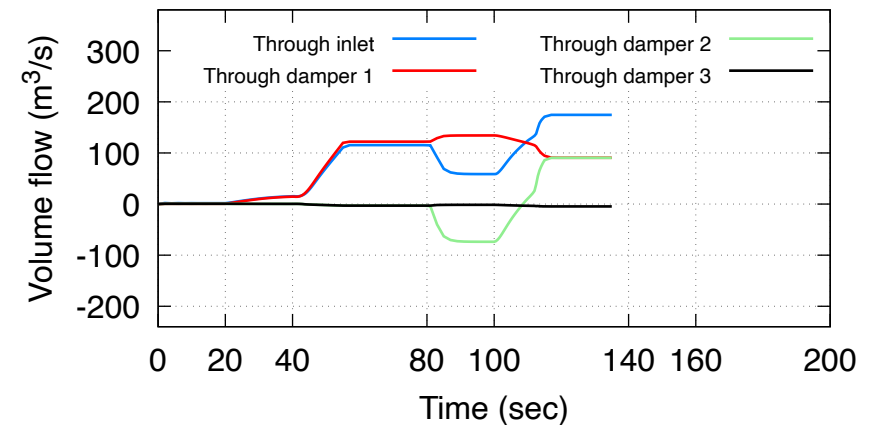
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Transient volume flows in the system



How not to run fans in parallel

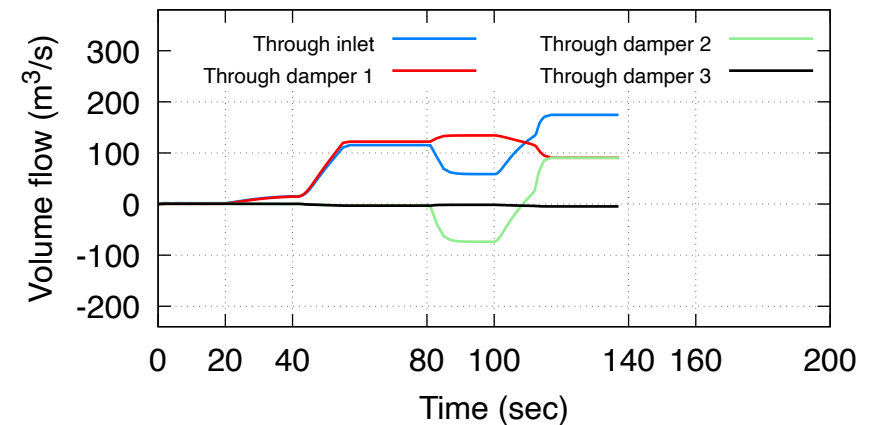
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Transient volume flows in the system



At 20 seconds, damper 1 opens

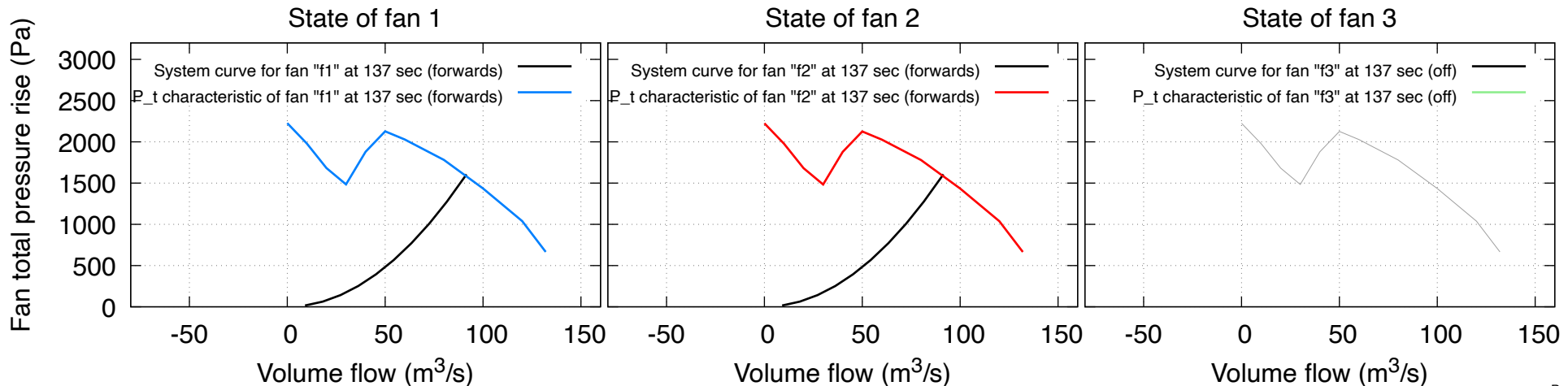
At 40 seconds, fan 1 starts

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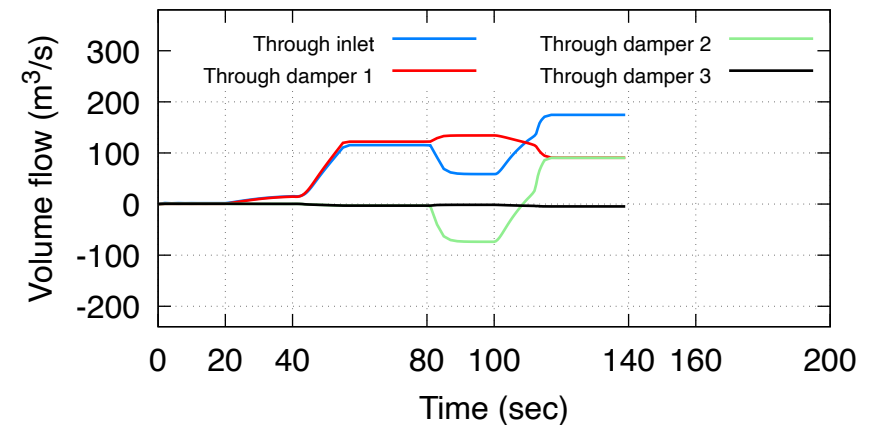
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Transient volume flows in the system



At 20 seconds, damper 1 opens

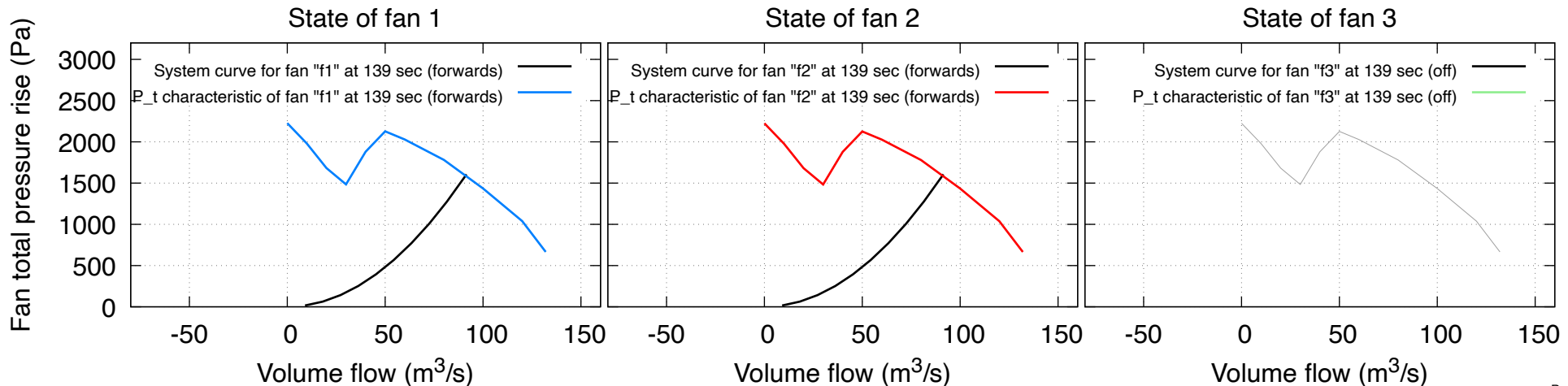
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

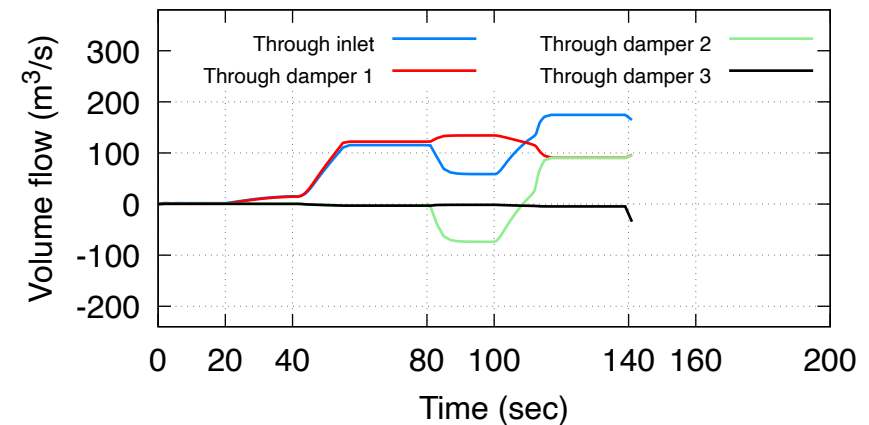
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Transient volume flows in the system



At 20 seconds, damper 1 opens

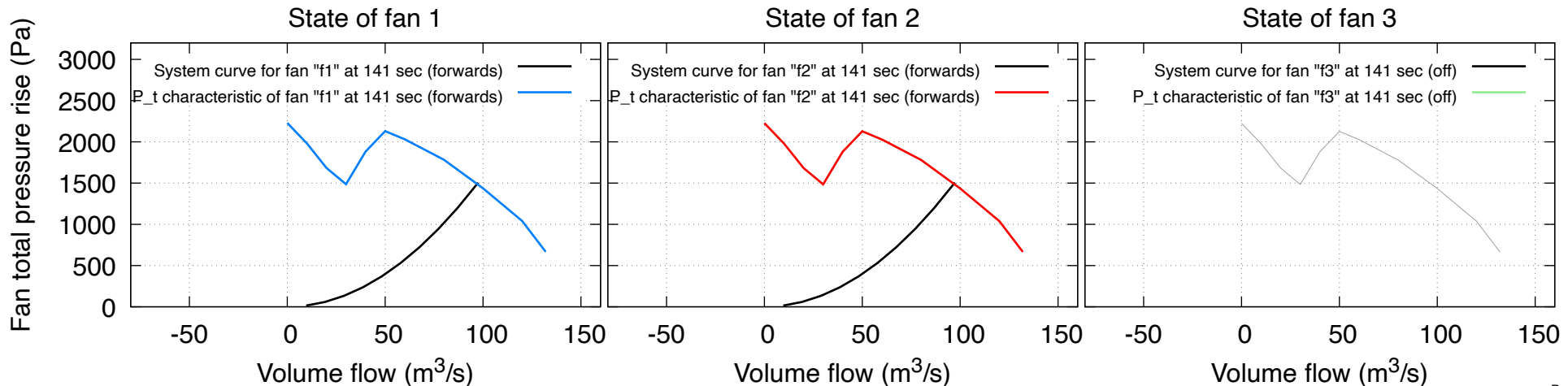
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

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At 160 seconds, fan 3 starts



How not to run fans in parallel

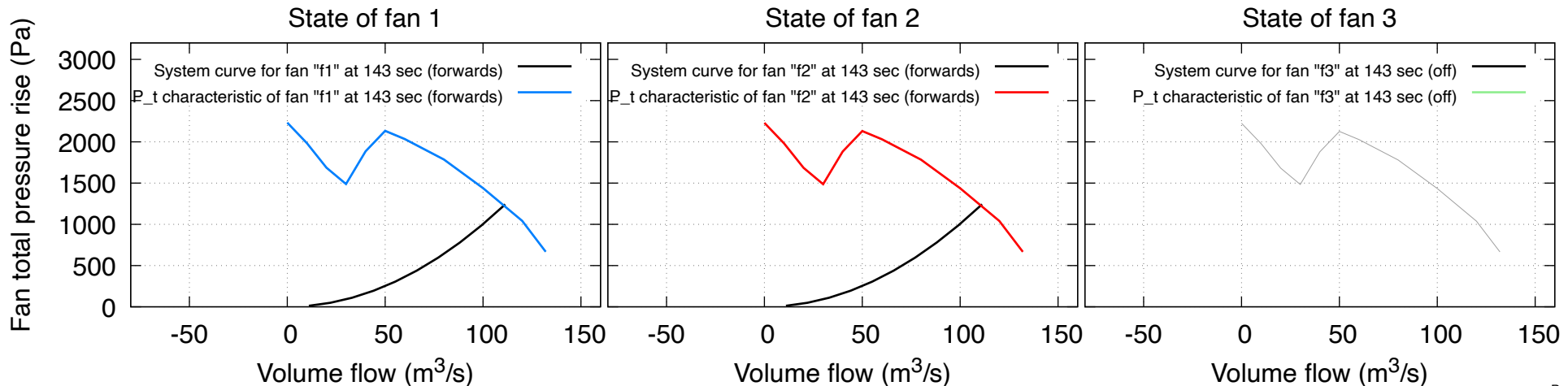
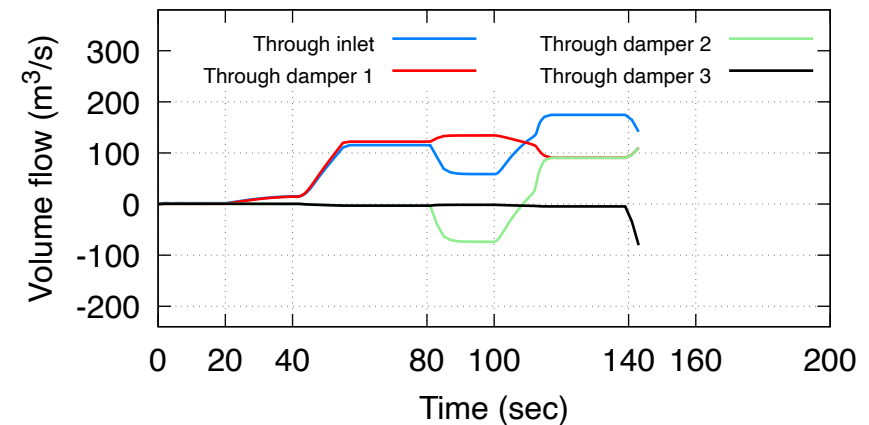
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Transient volume flows in the system



How not to run fans in parallel

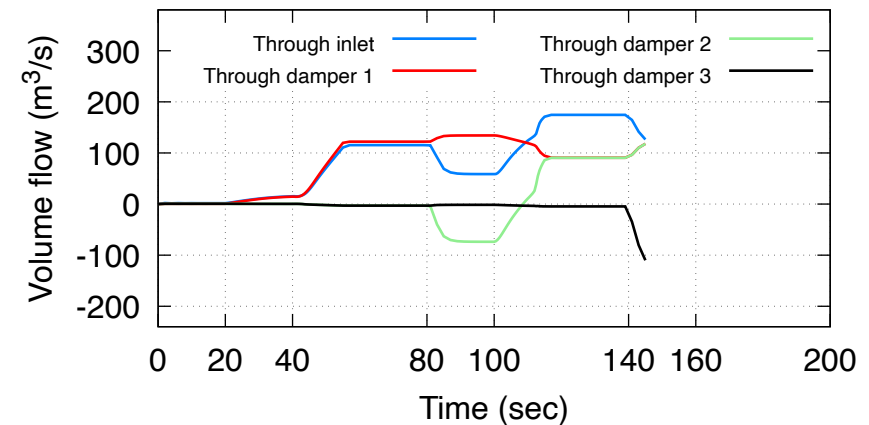
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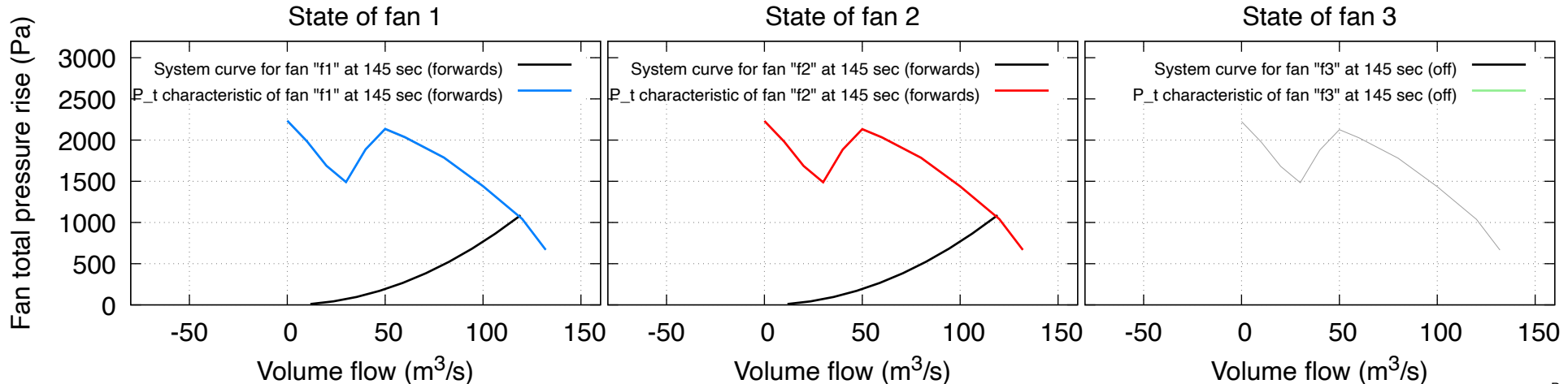
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

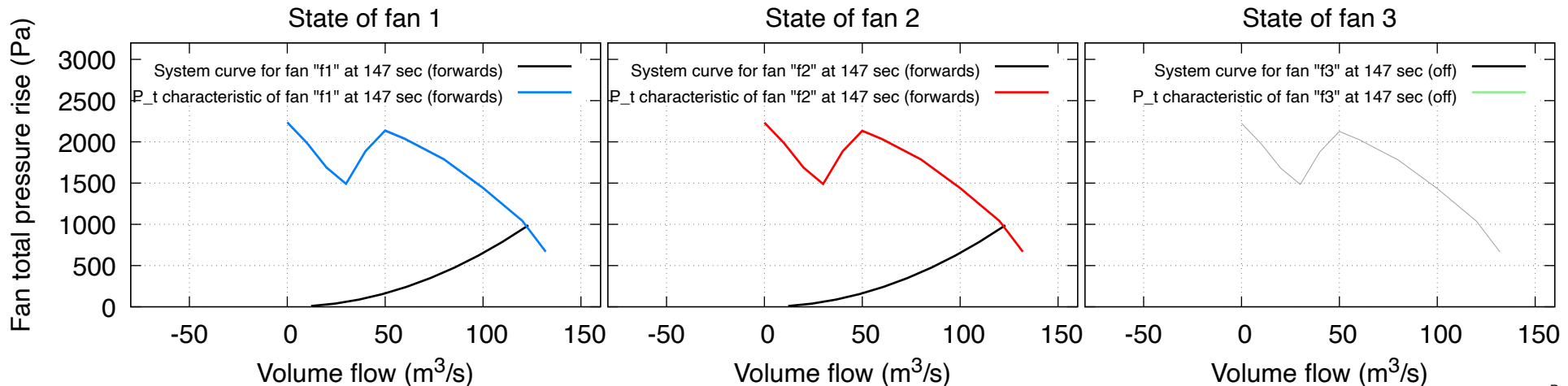
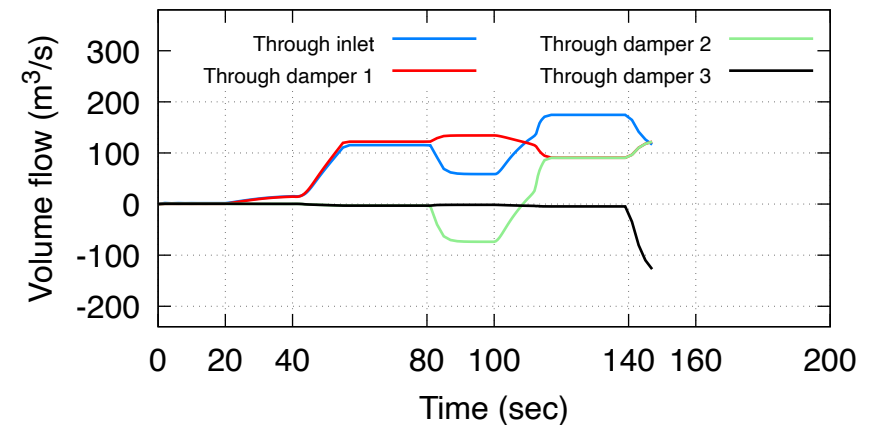
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Transient volume flows in the system



How not to run fans in parallel

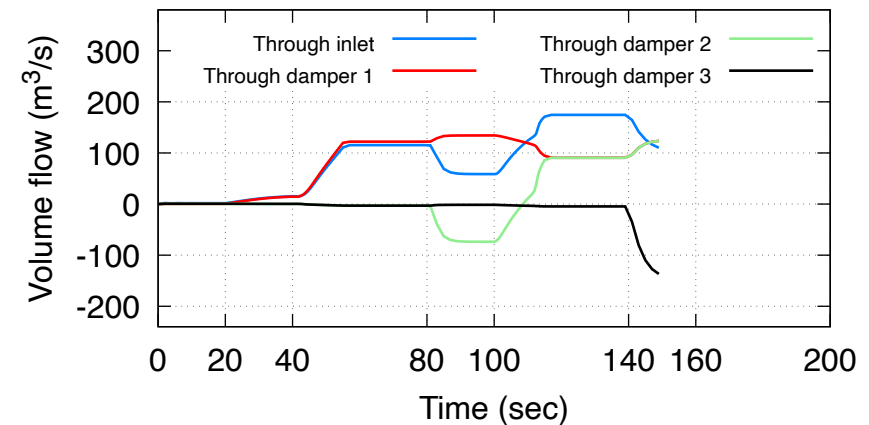
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

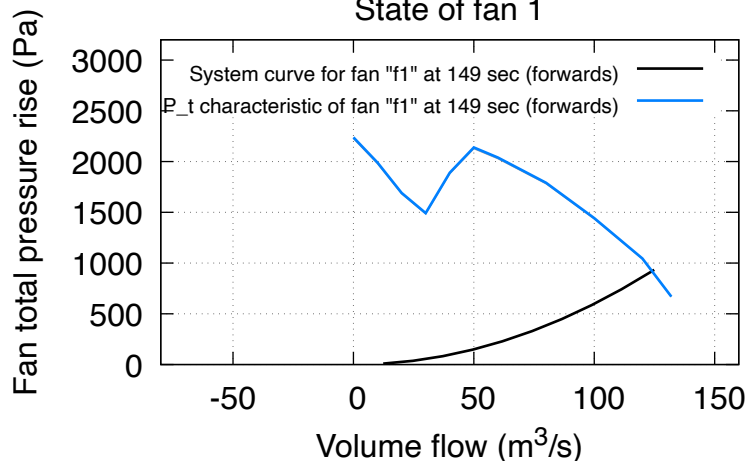
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

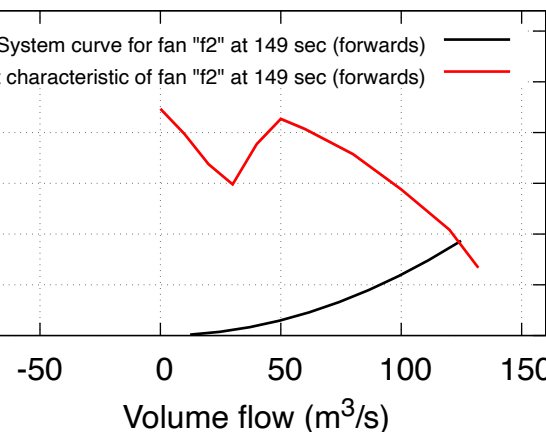
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

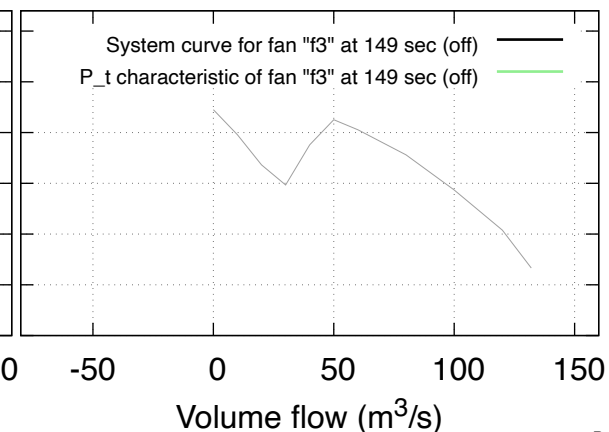
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

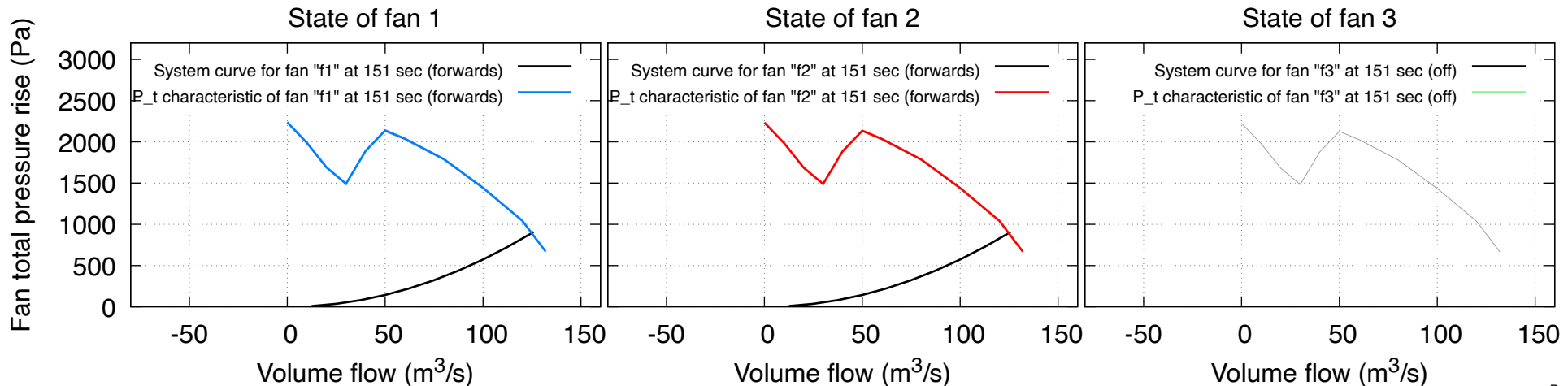
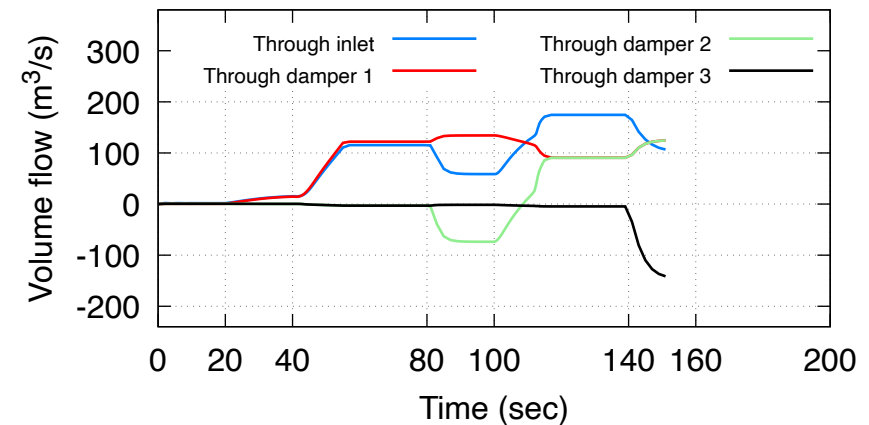
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Transient volume flows in the system



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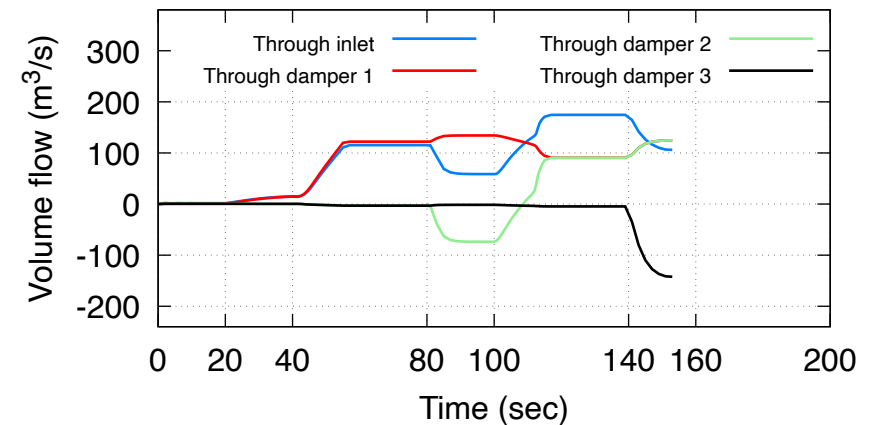
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

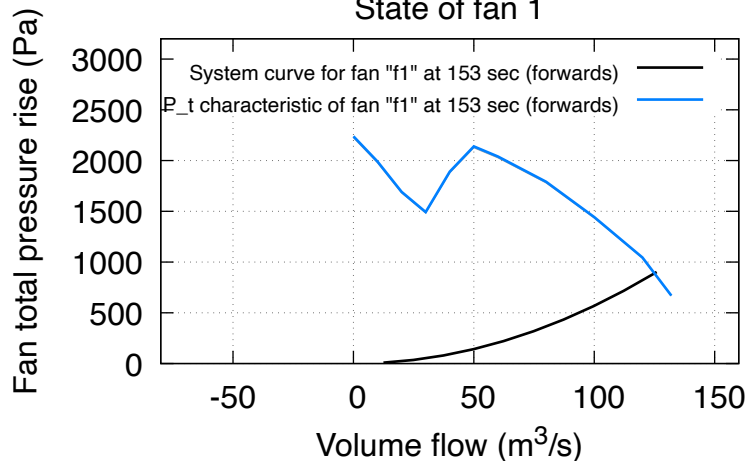
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

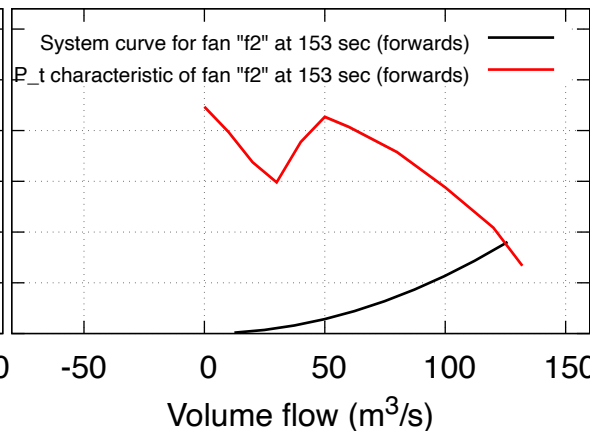
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

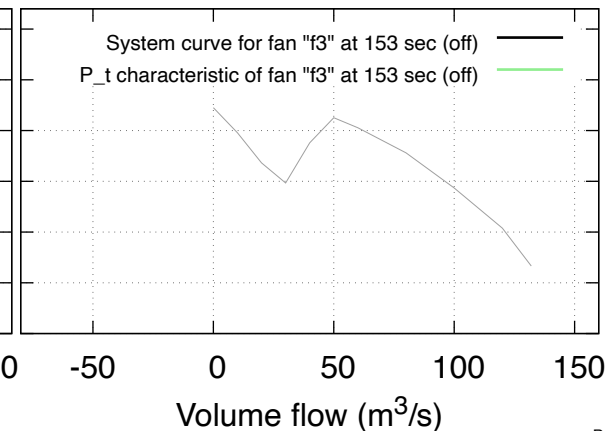
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

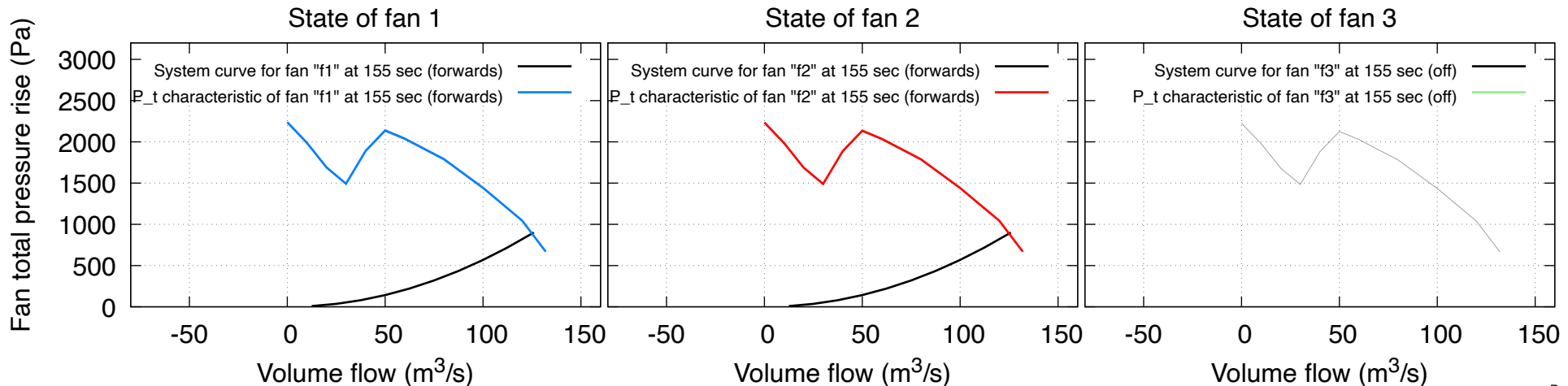
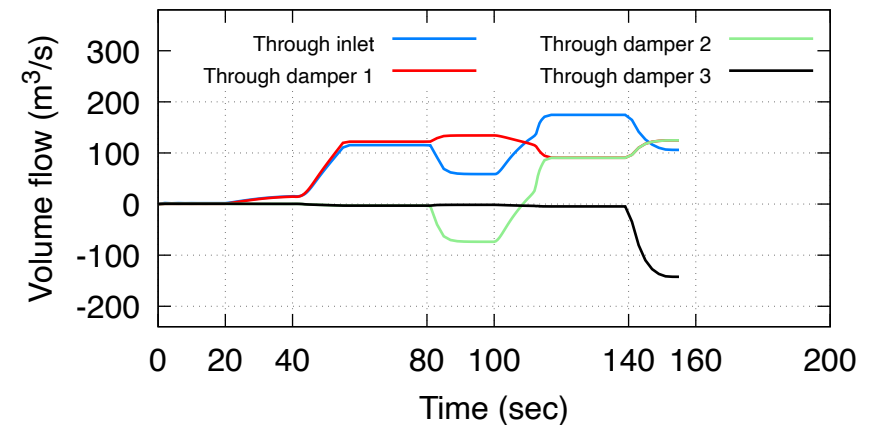
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Transient volume flows in the system



How not to run fans in parallel

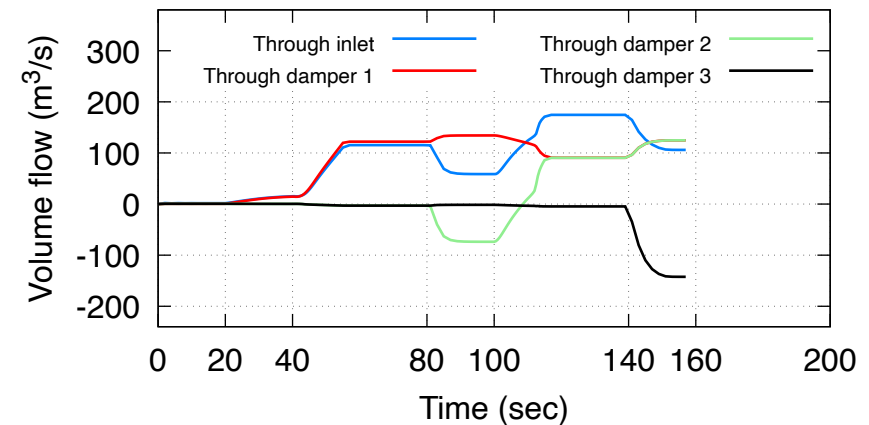
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

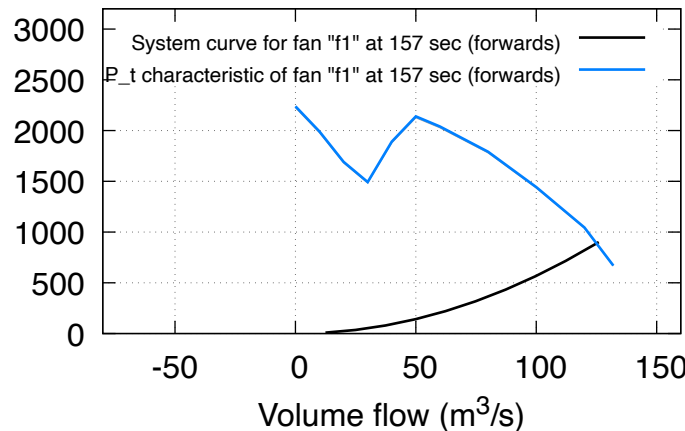
At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

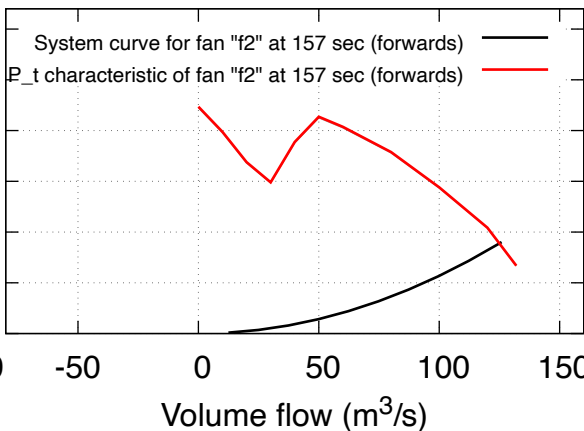
At 160 seconds, fan 3 starts

Fan total pressure rise (Pa)

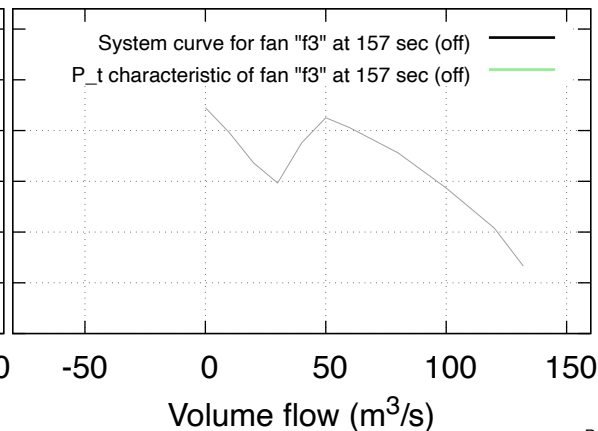
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

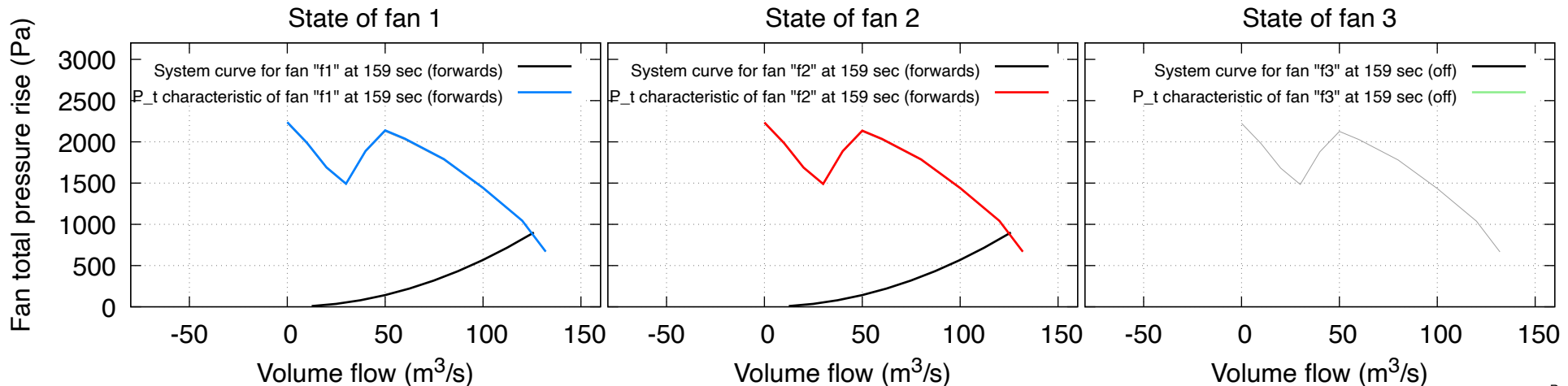
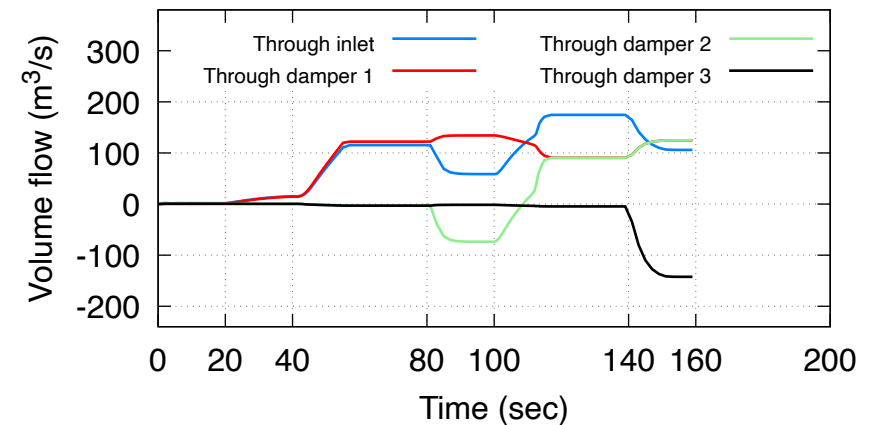
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Transient volume flows in the system



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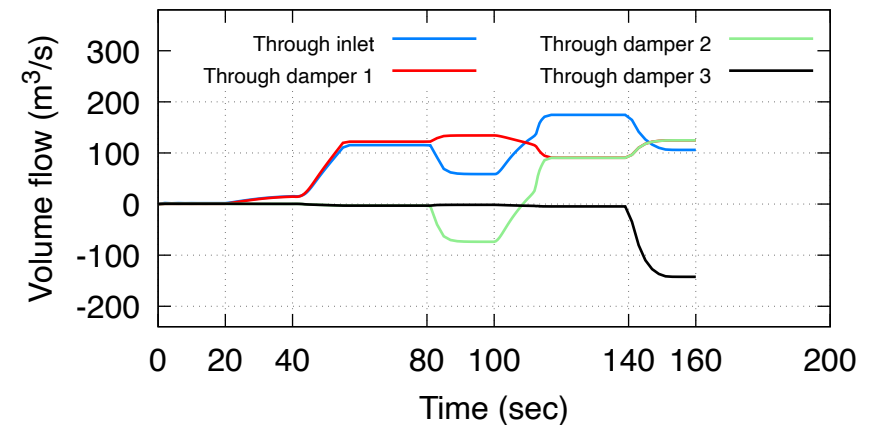
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Transient volume flows in the system



At 20 seconds, damper 1 opens

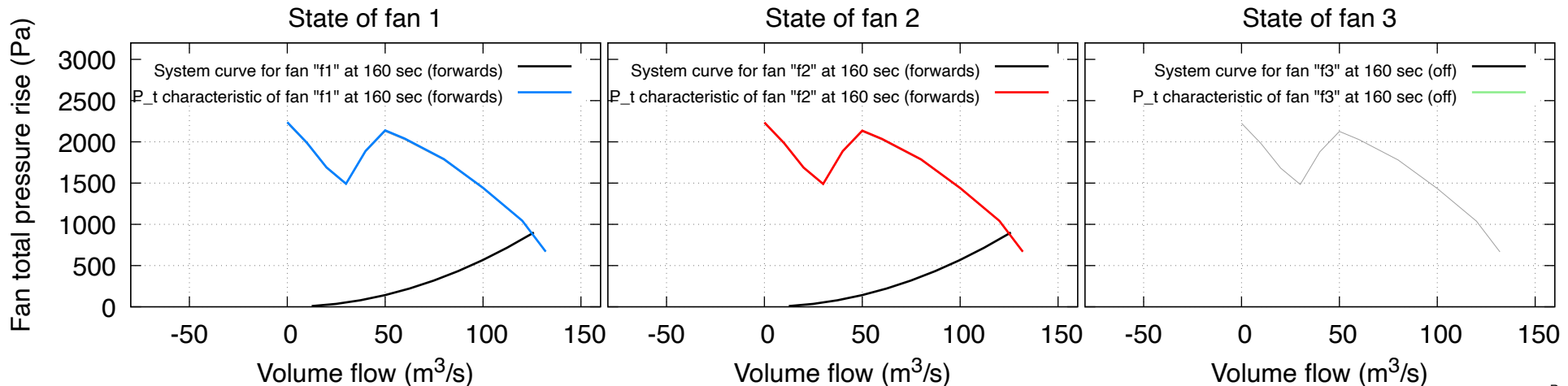
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

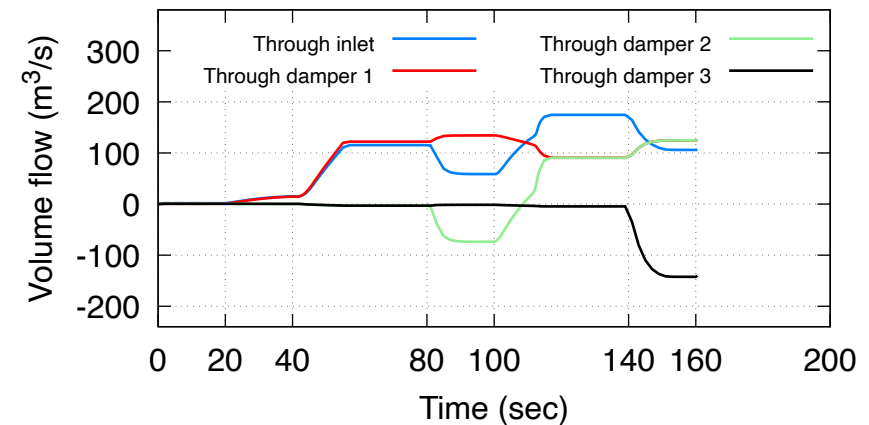
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Transient volume flows in the system



At 20 seconds, damper 1 opens

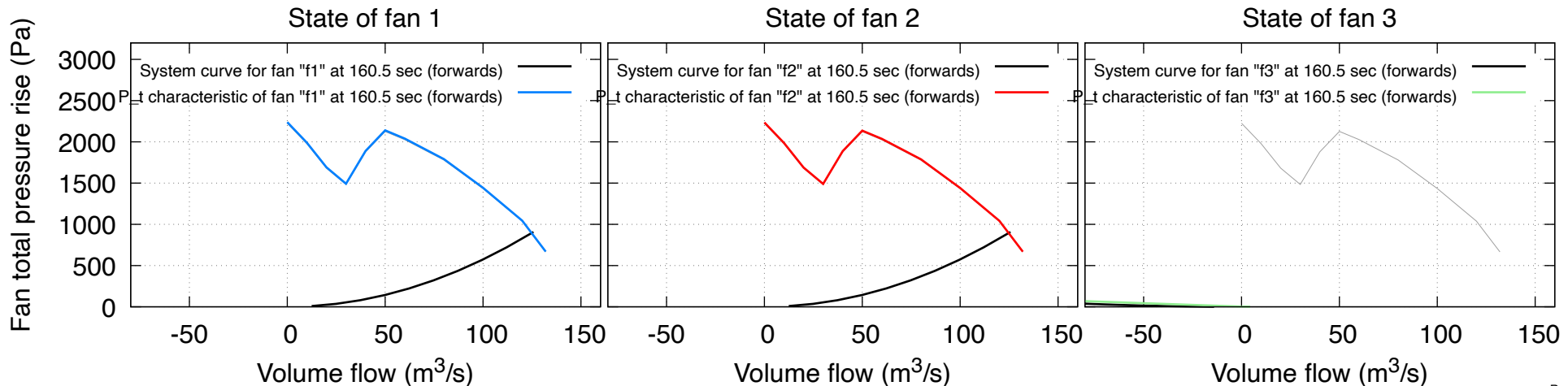
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

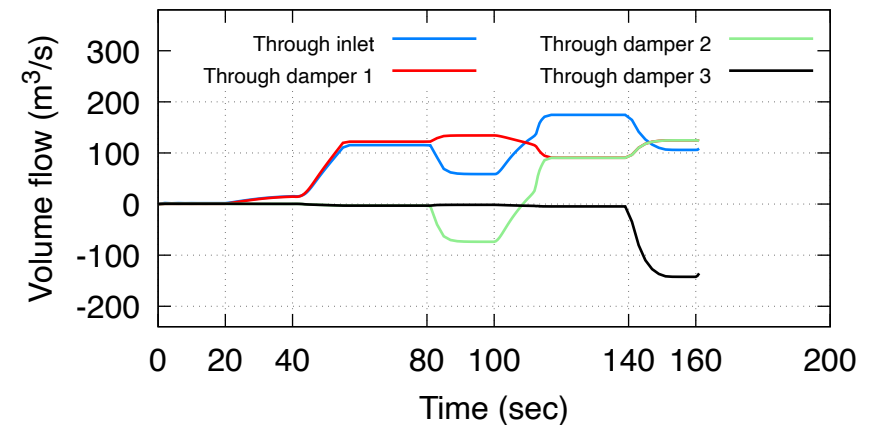
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

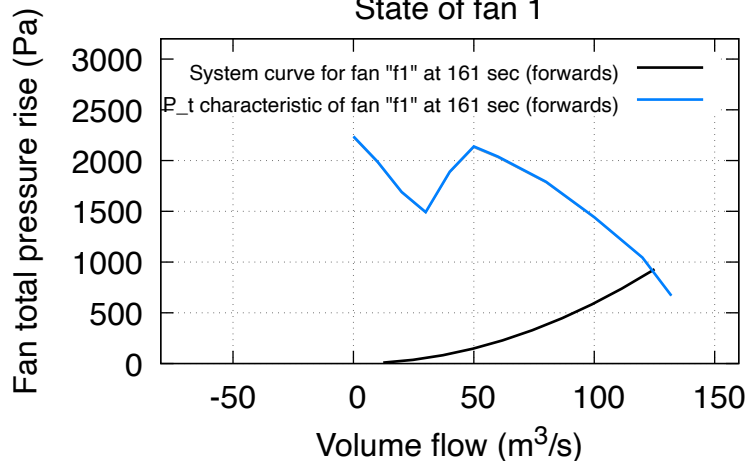
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

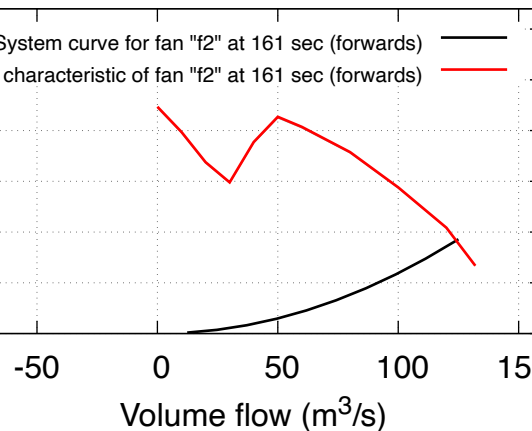
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

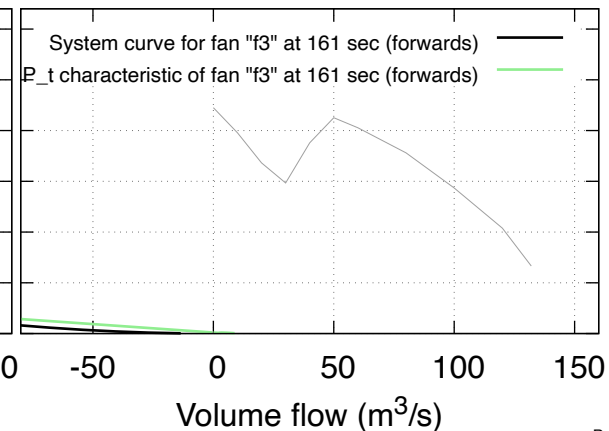
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

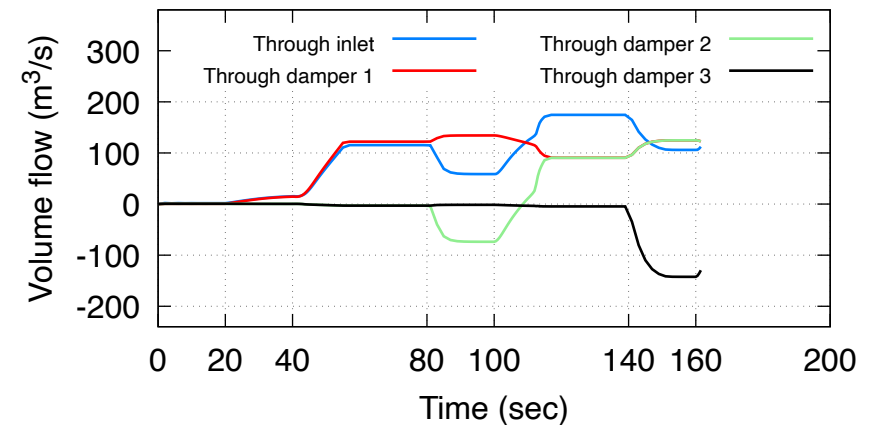
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Transient volume flows in the system



At 20 seconds, damper 1 opens

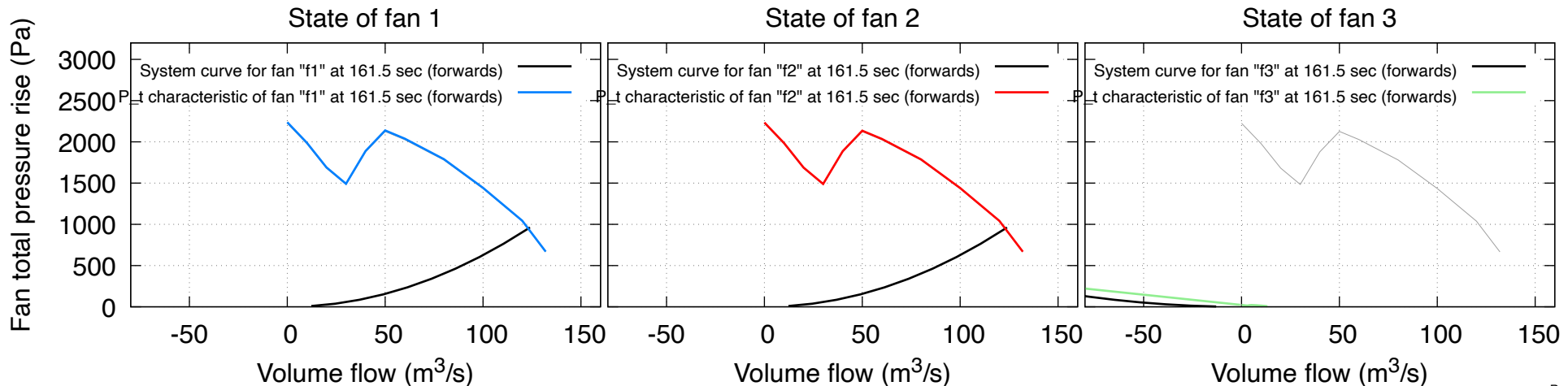
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

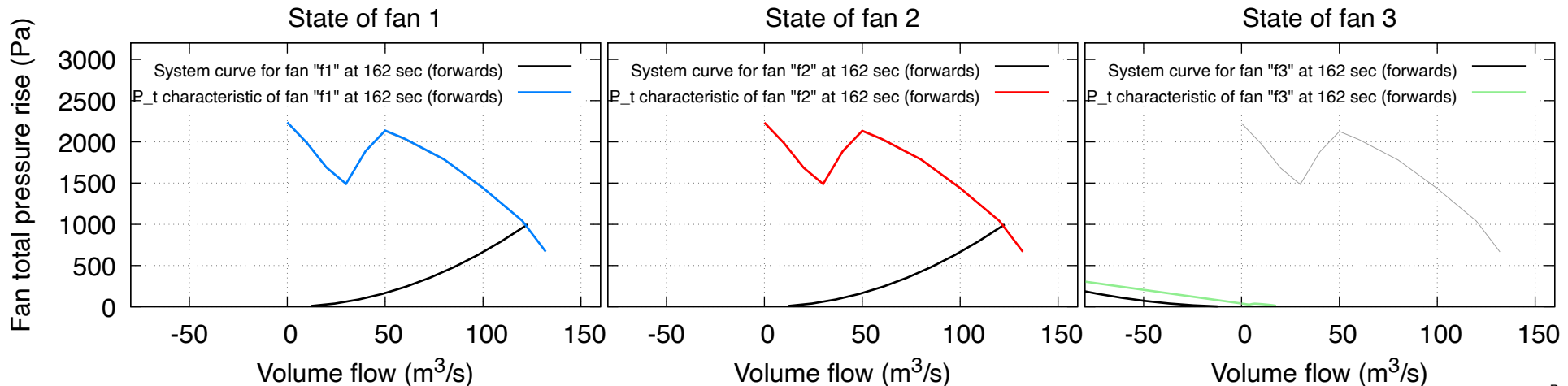
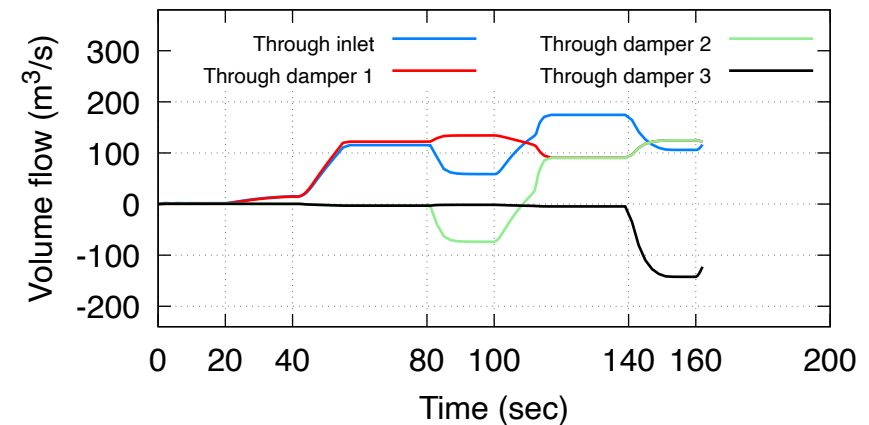
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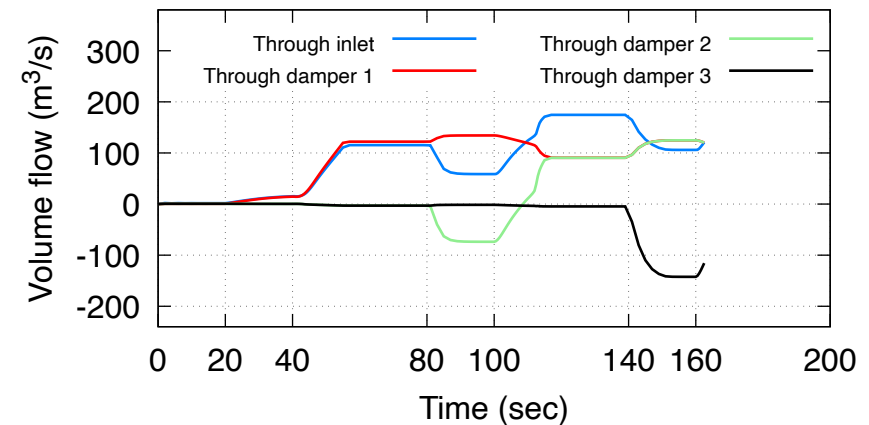
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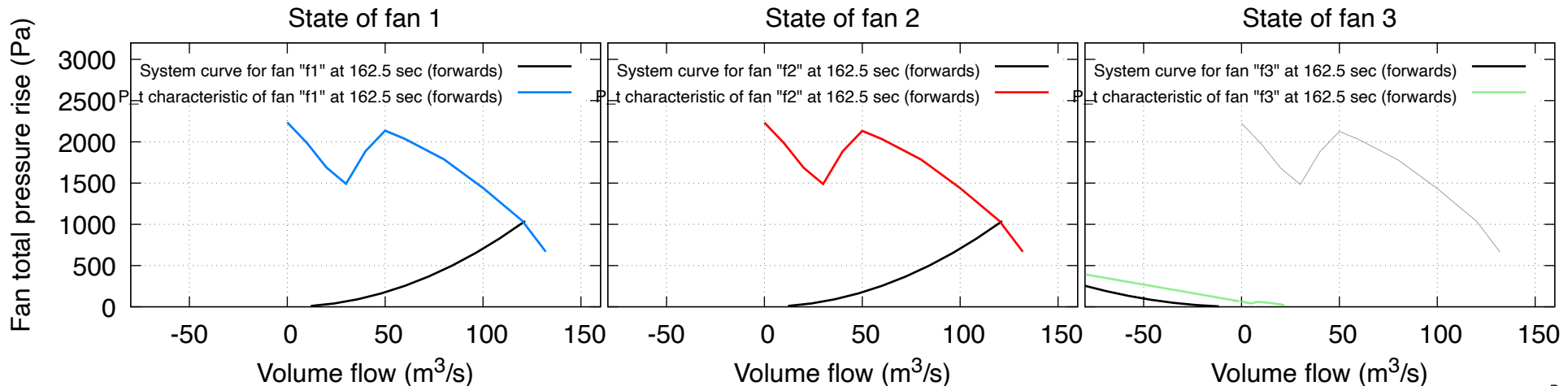
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How not to run fans in parallel

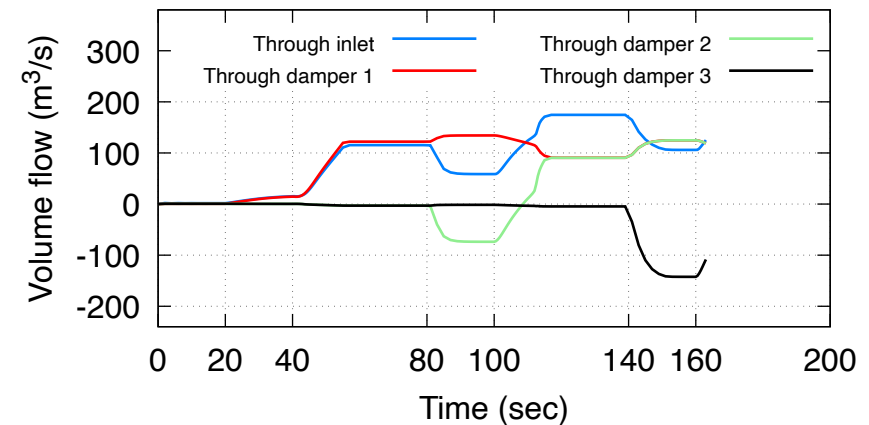
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Transient volume flows in the system



At 20 seconds, damper 1 opens

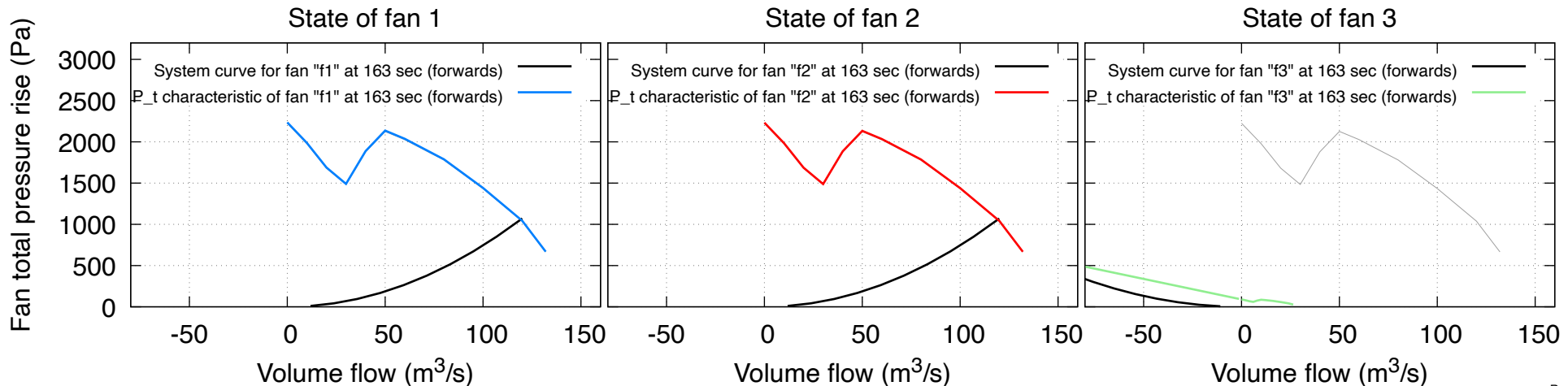
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How not to run fans in parallel

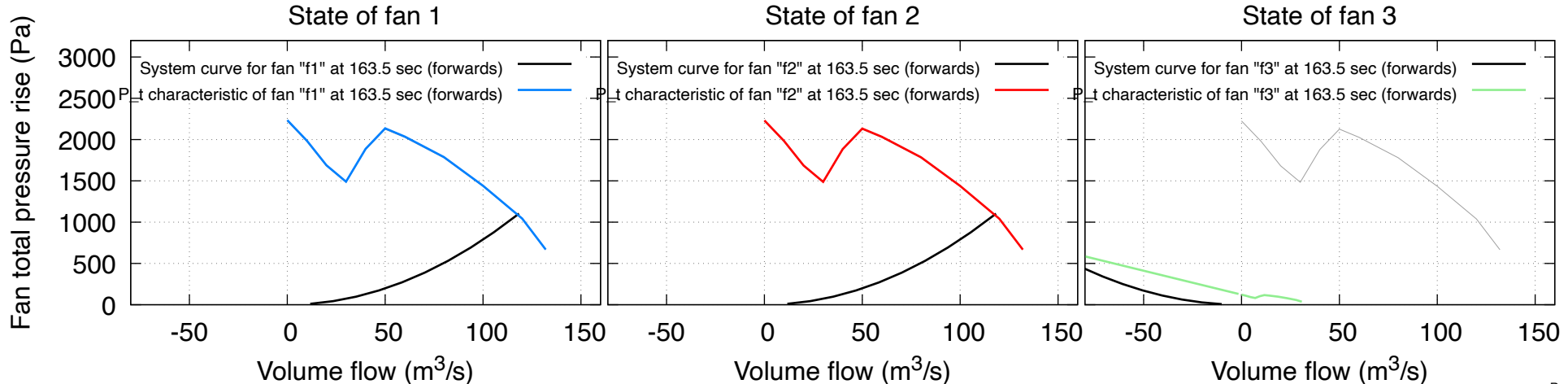
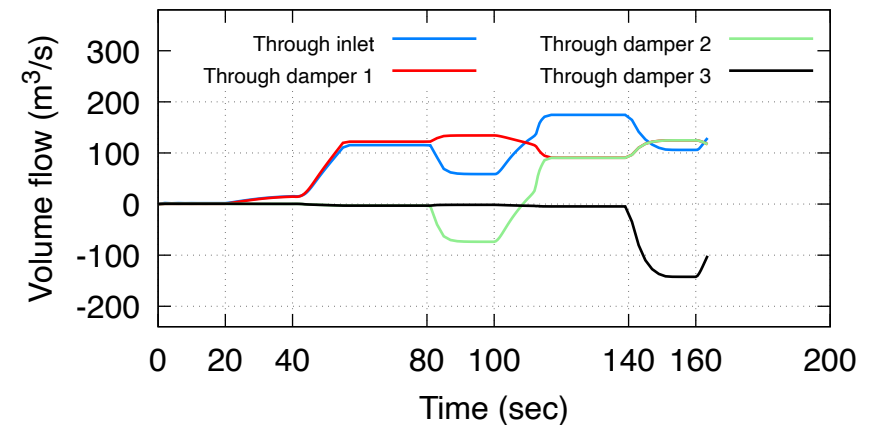
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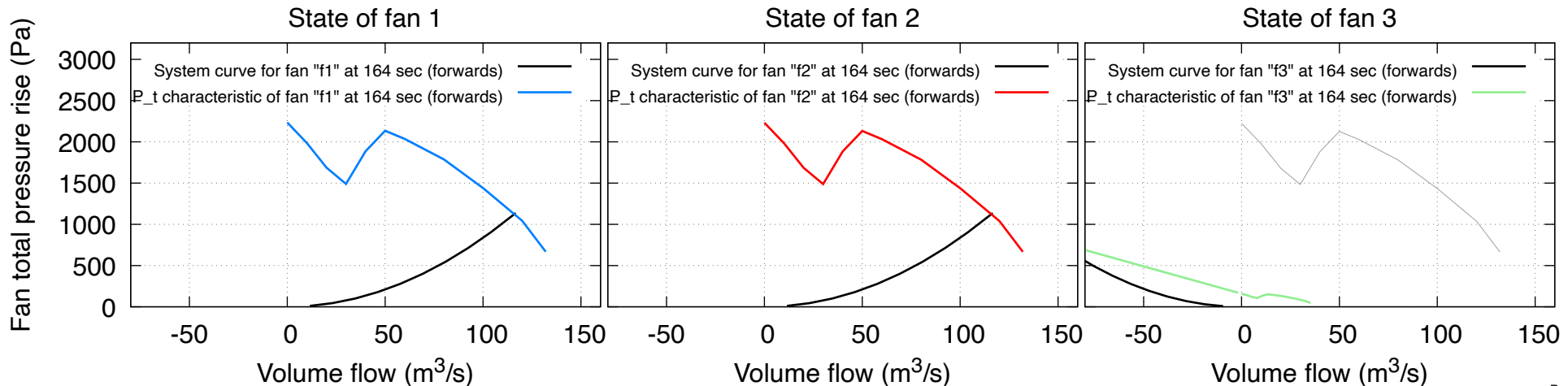
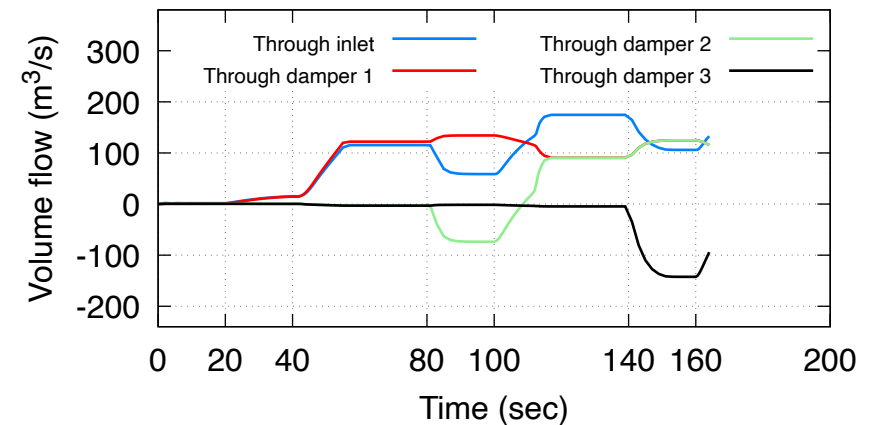
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Transient volume flows in the system



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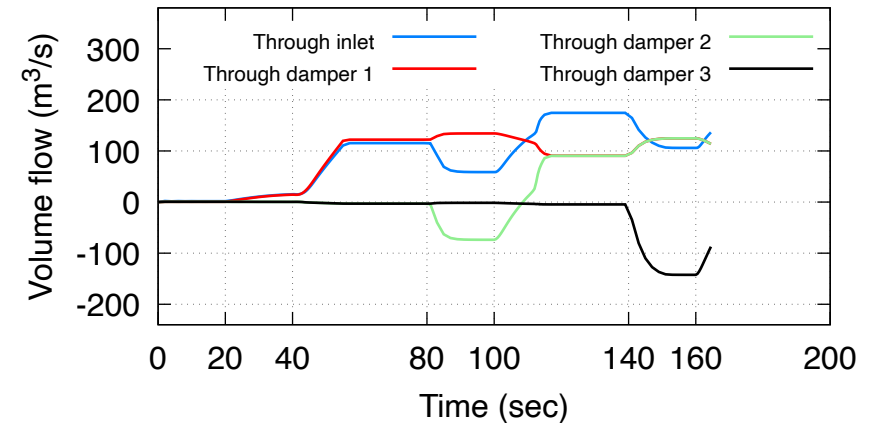
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Transient volume flows in the system



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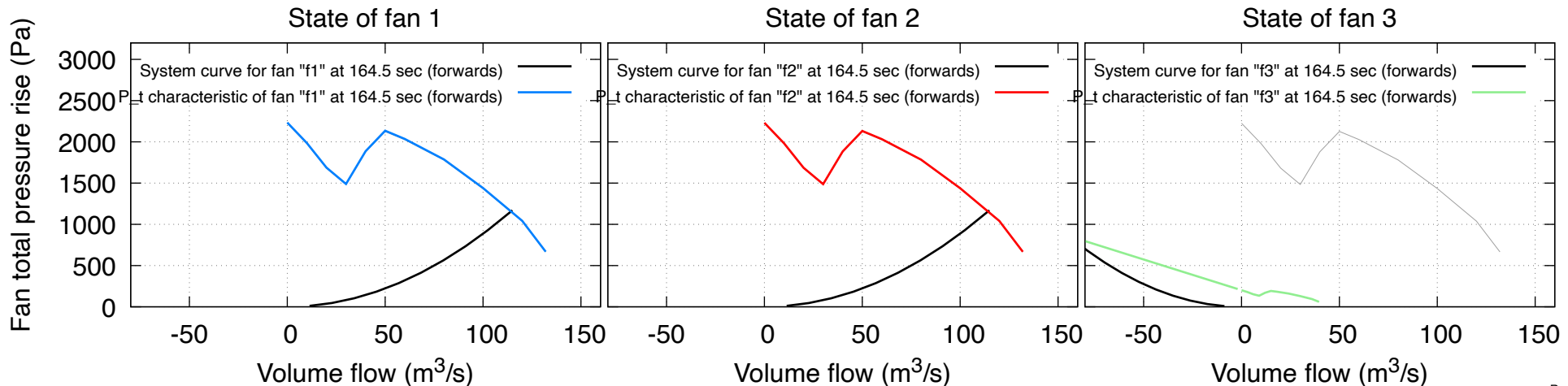
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How not to run fans in parallel

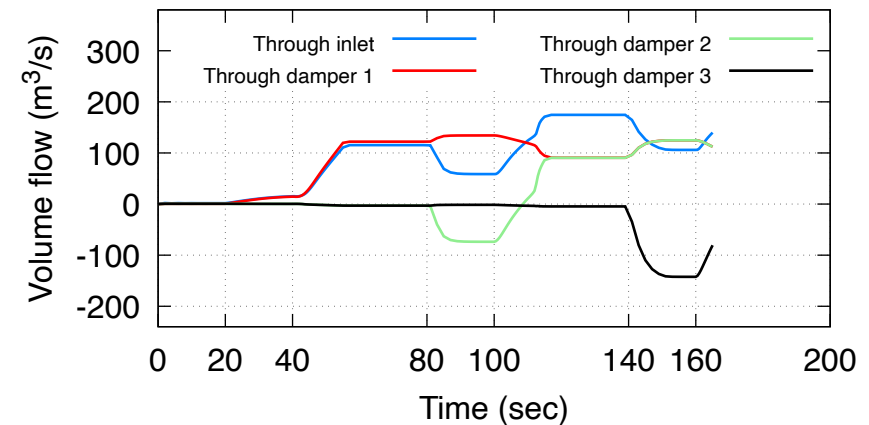
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

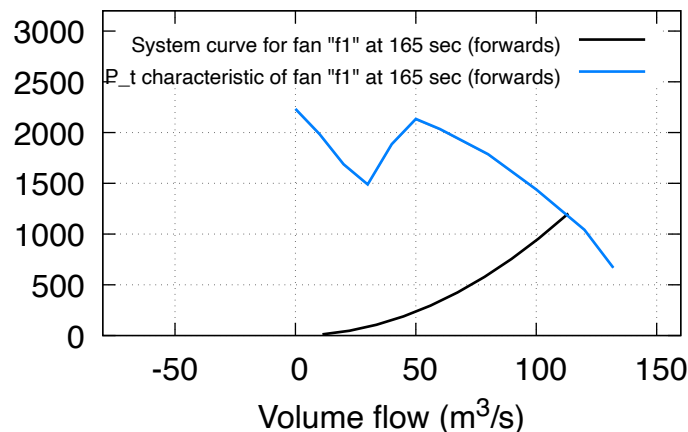
At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

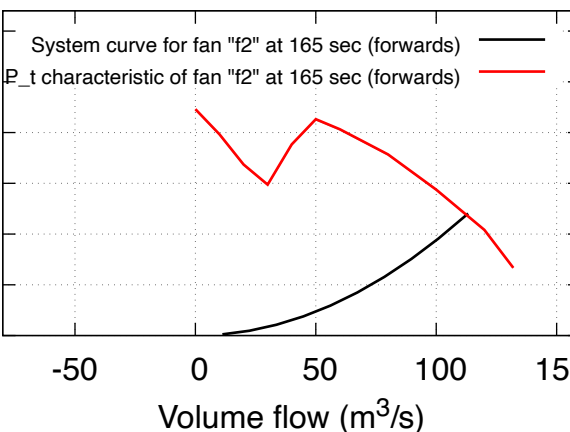
At 160 seconds, fan 3 starts

Fan total pressure rise (Pa)

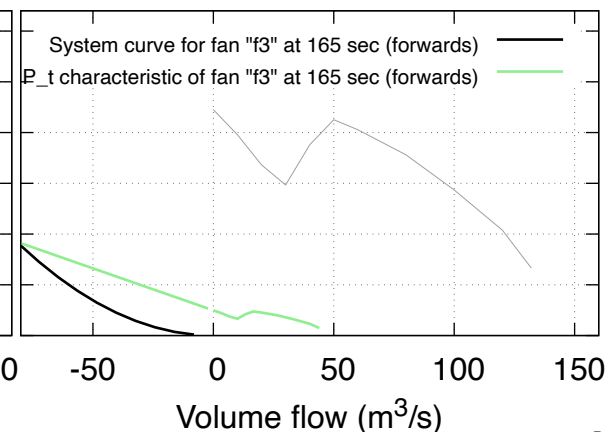
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

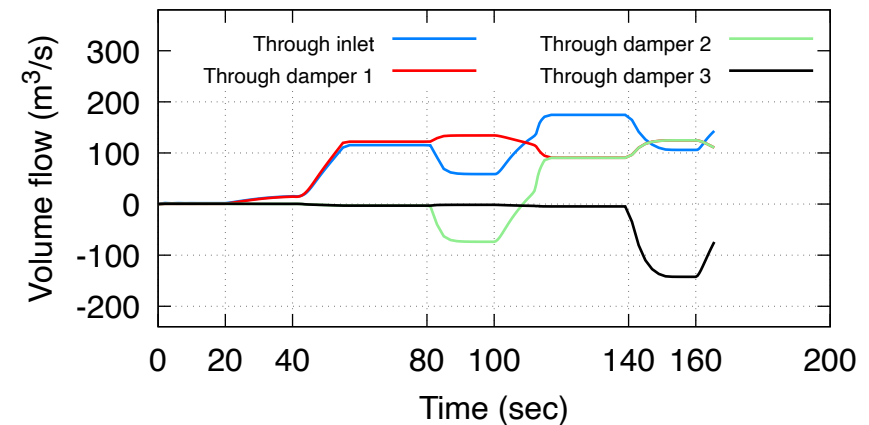
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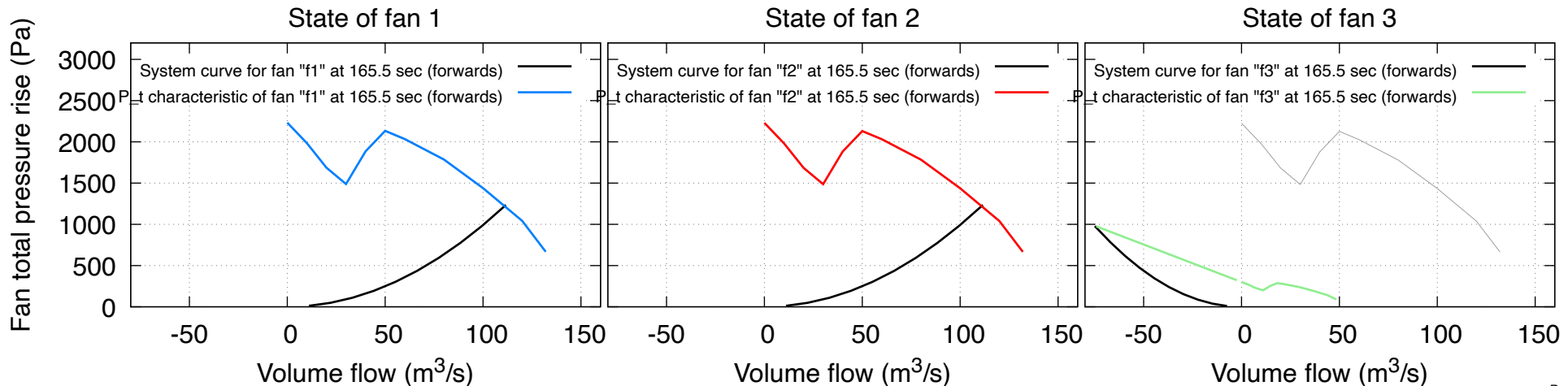
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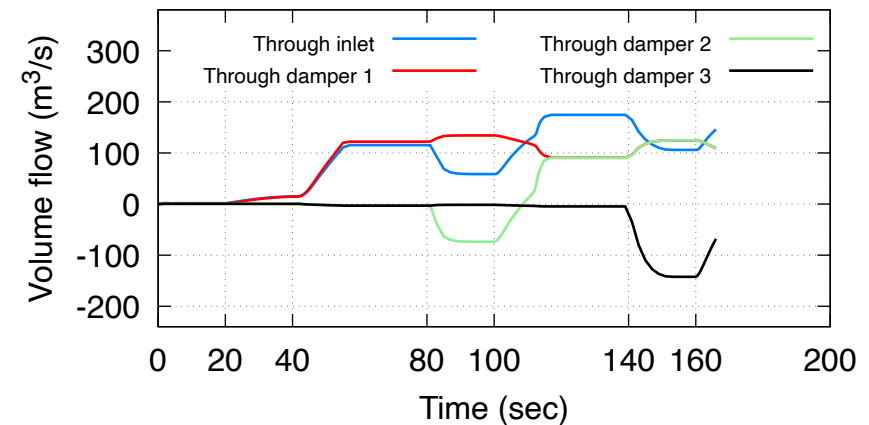
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Transient volume flows in the system



At 20 seconds, damper 1 opens

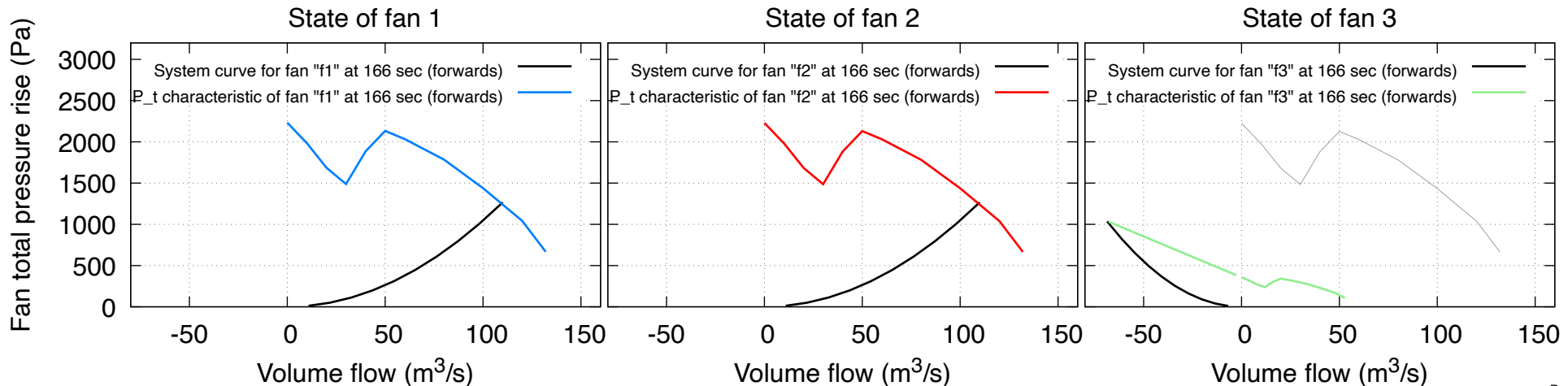
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How not to run fans in parallel

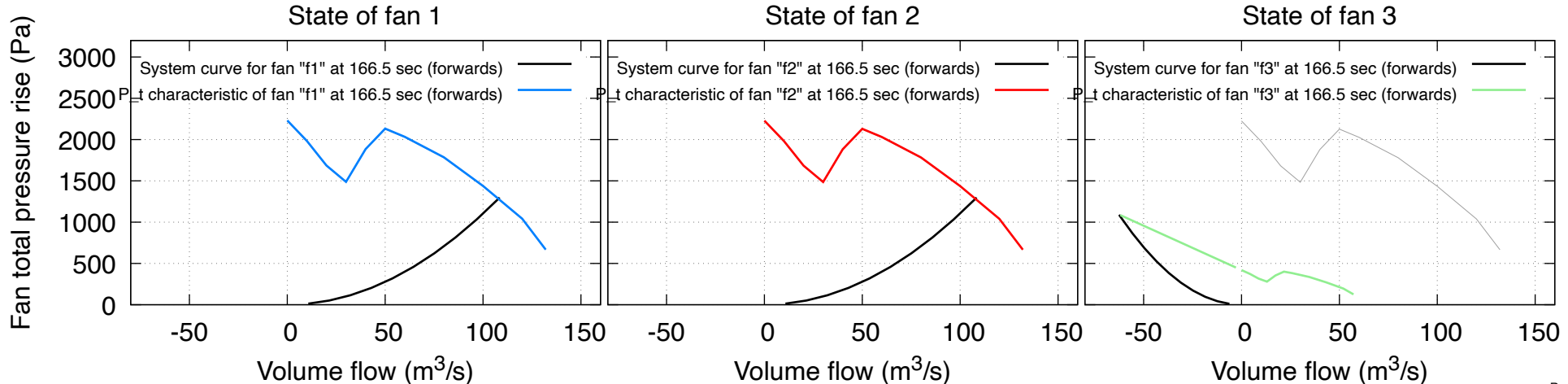
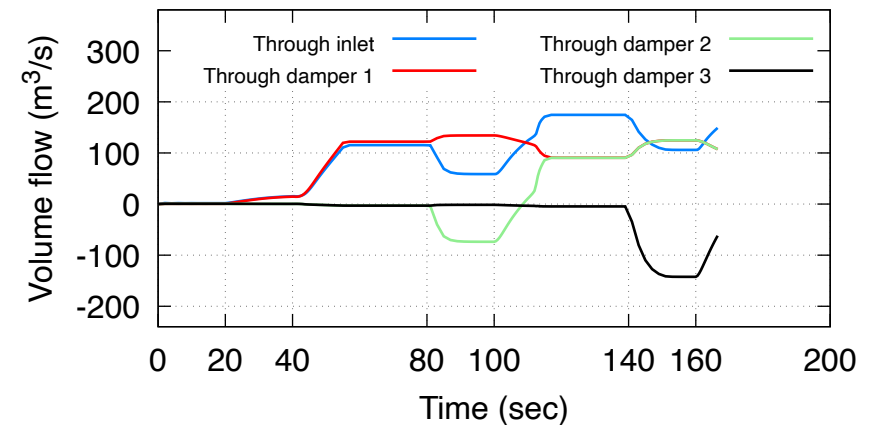
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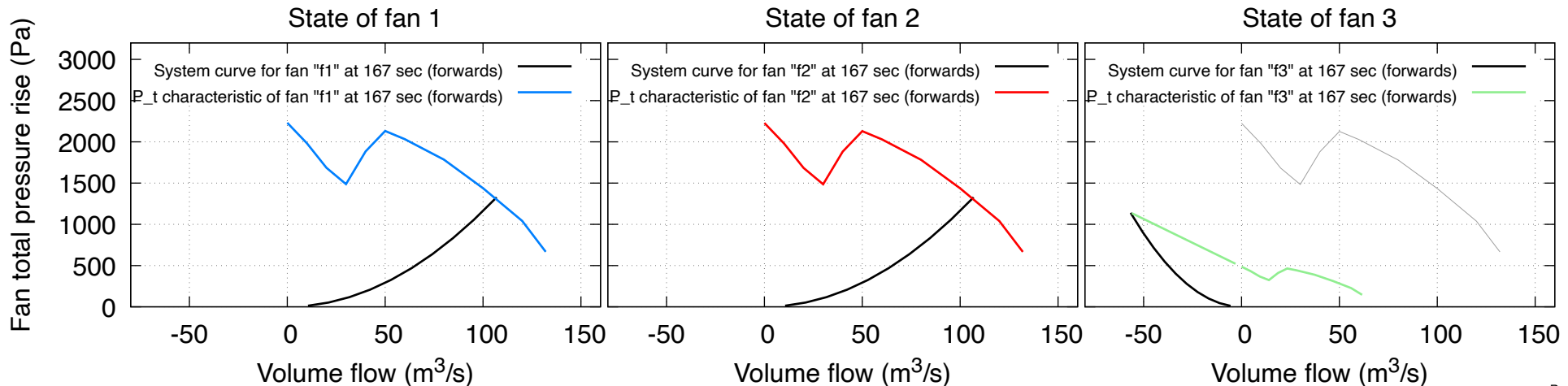
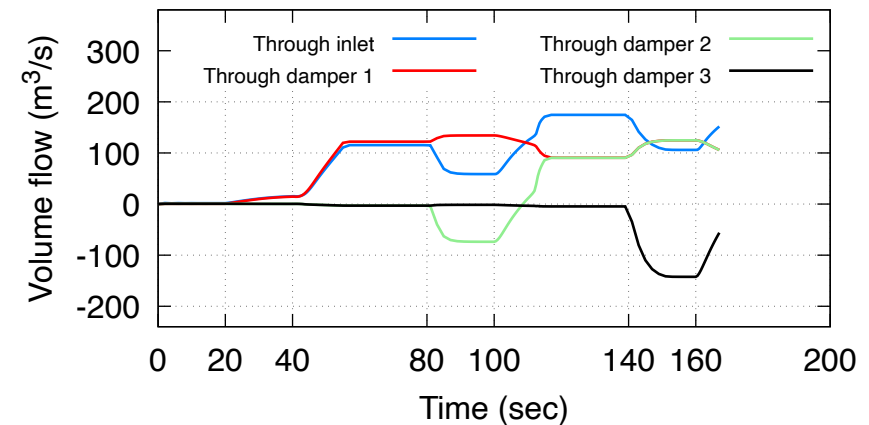
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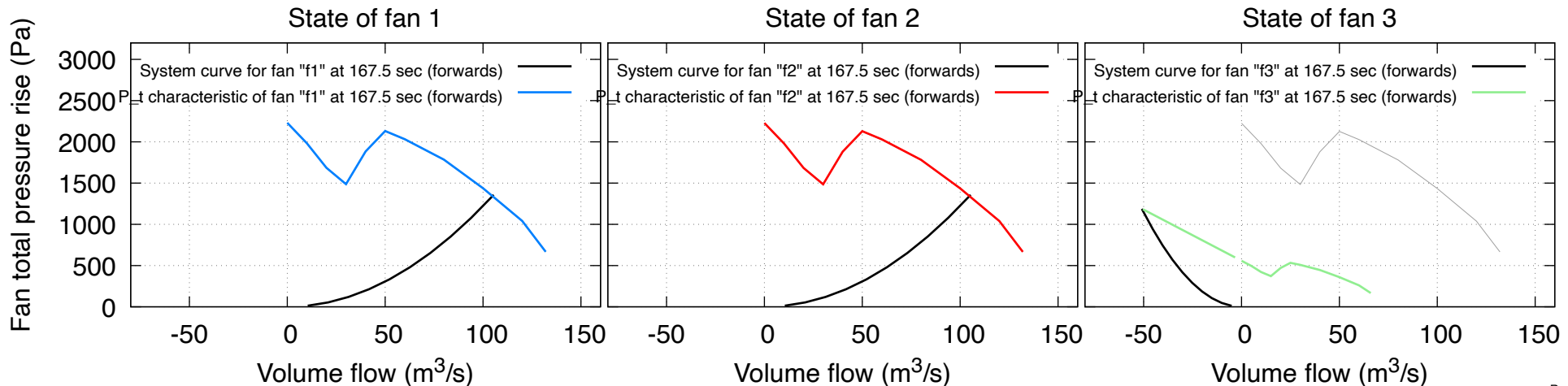
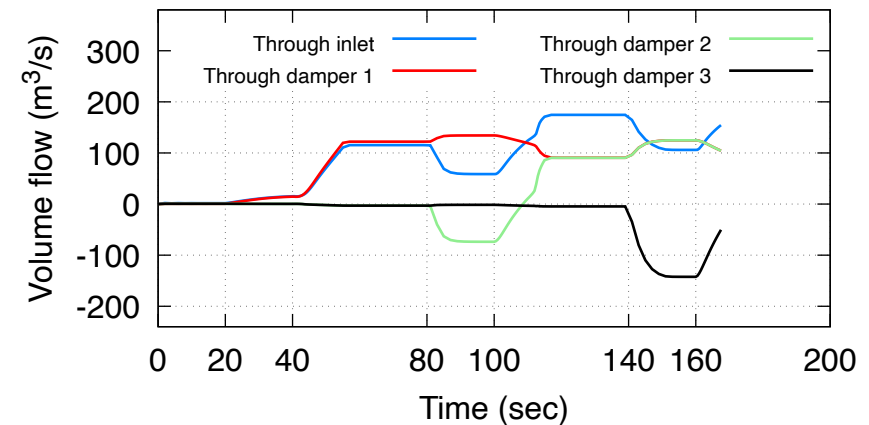
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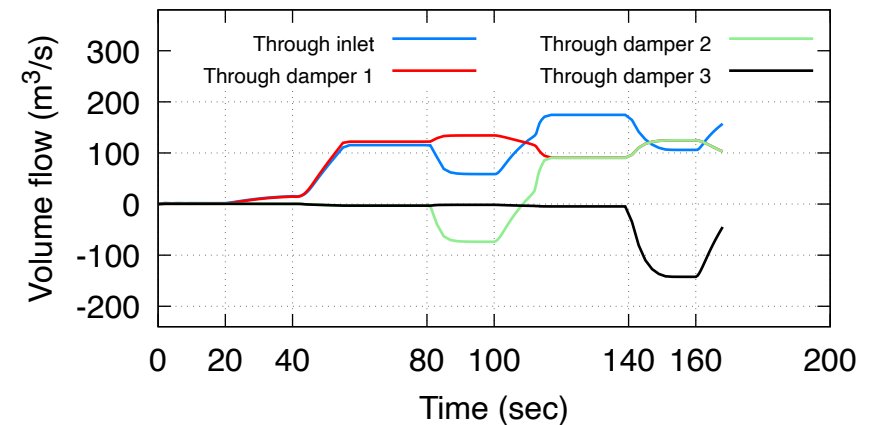
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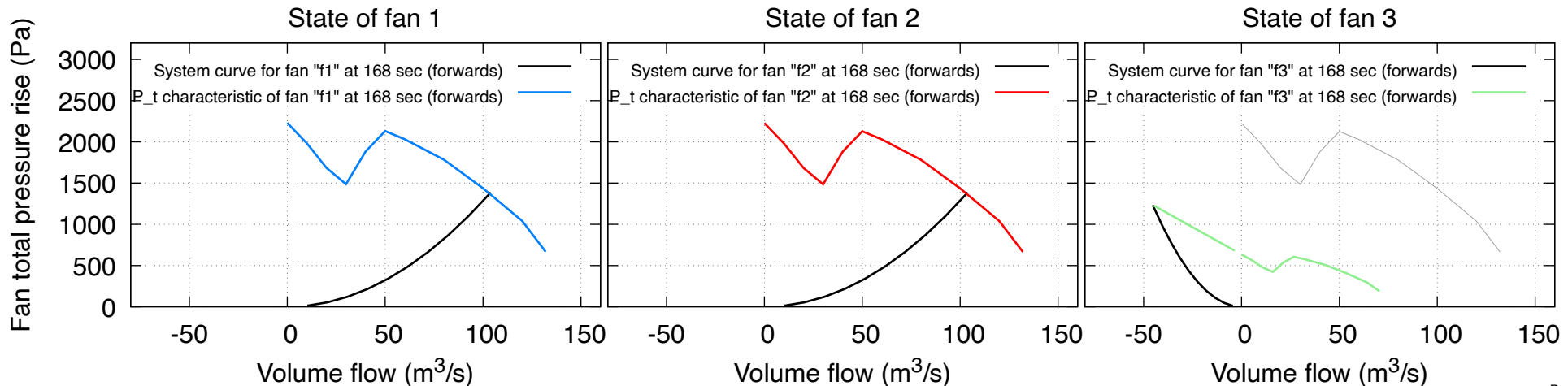
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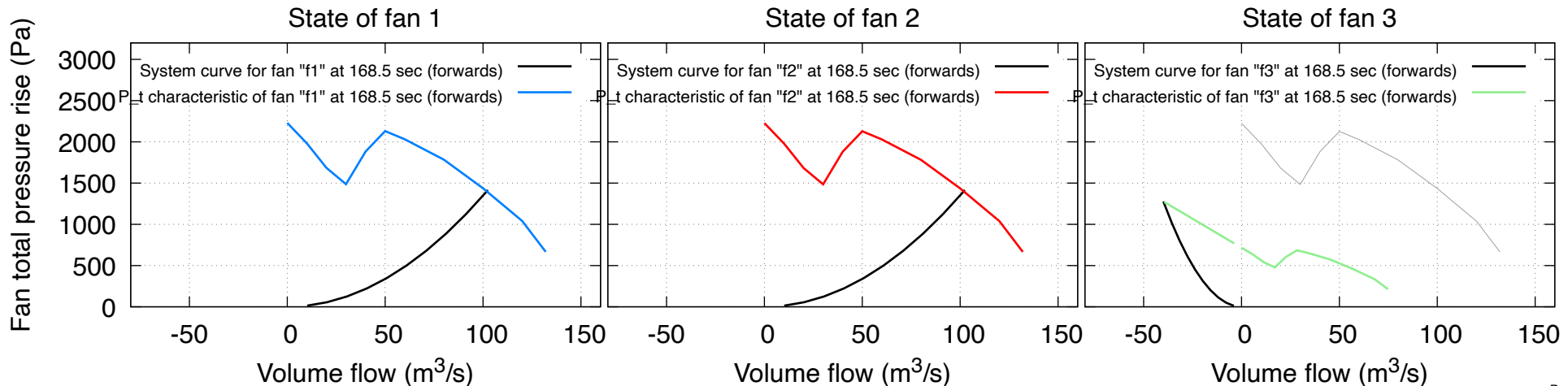
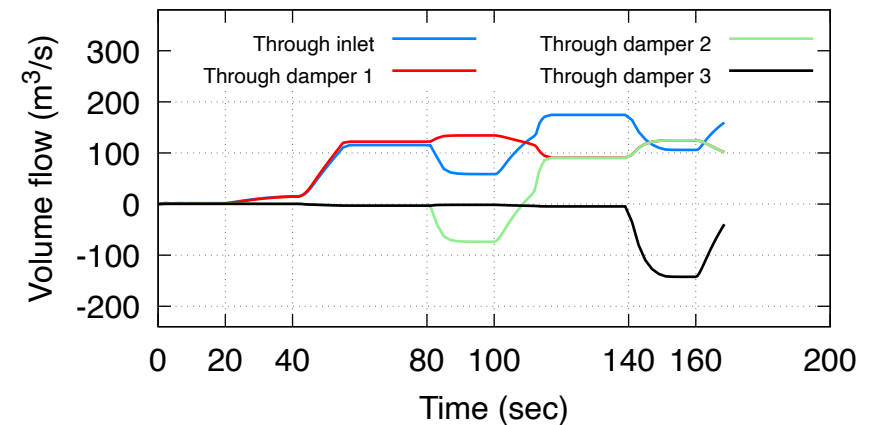
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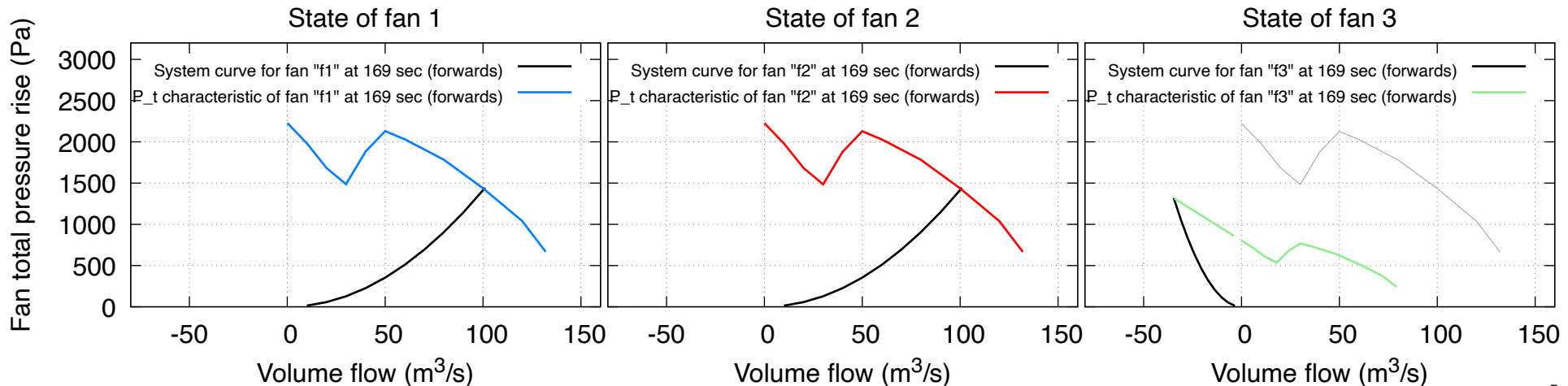
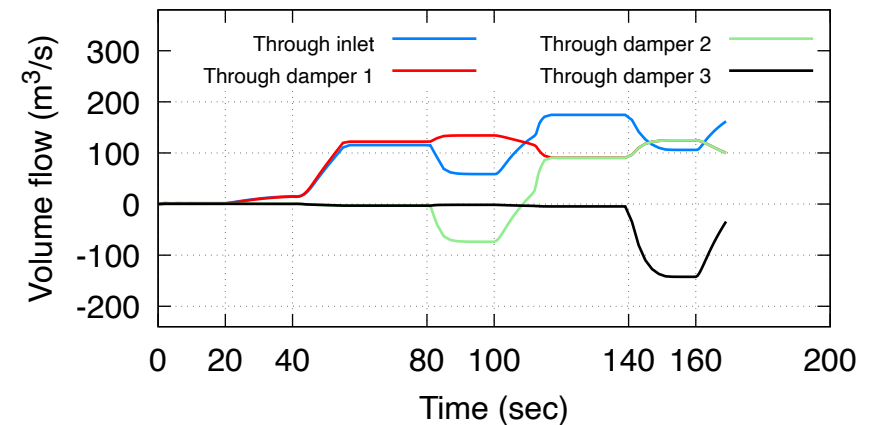
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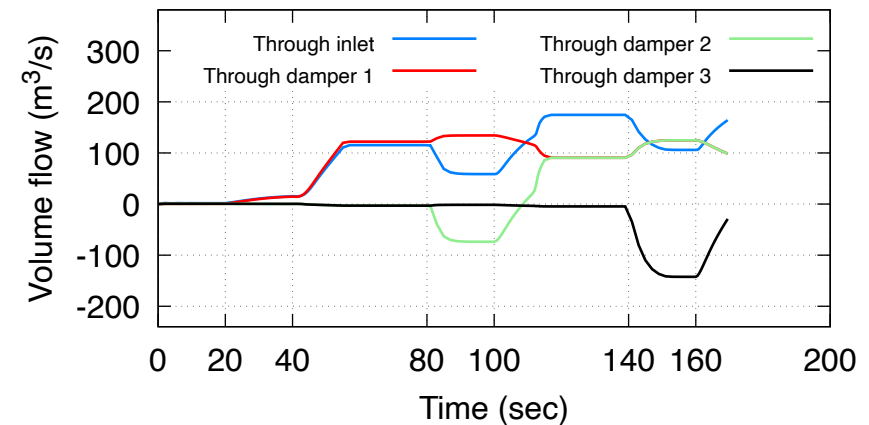
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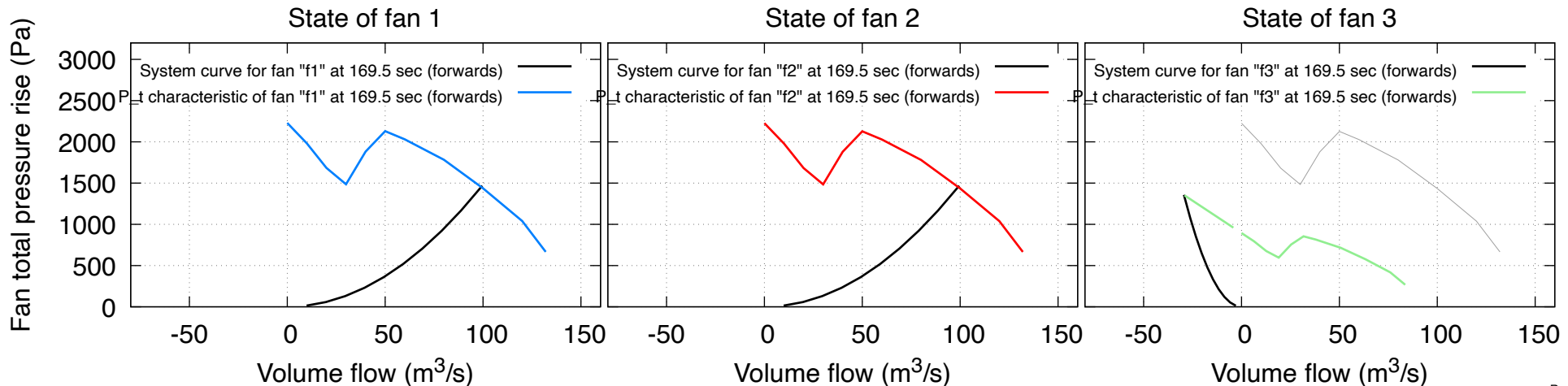
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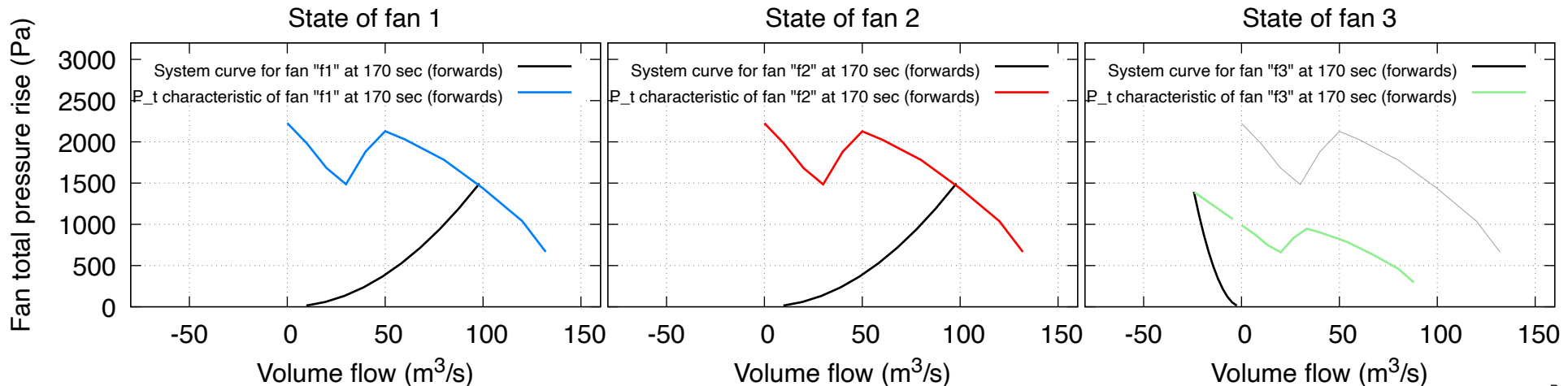
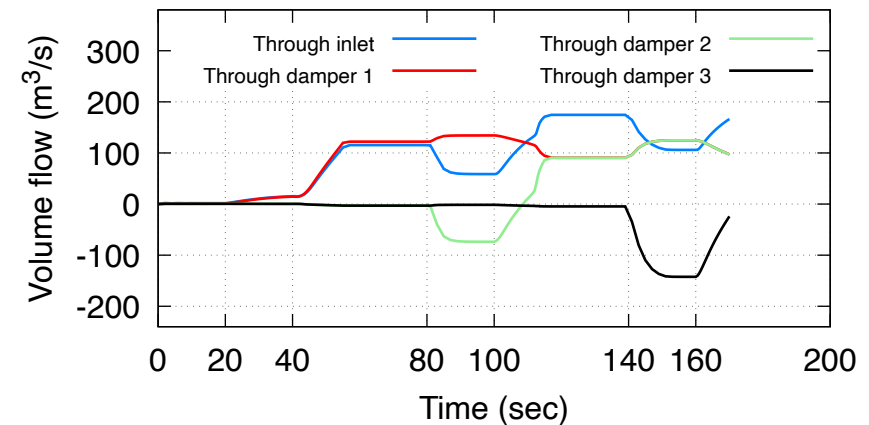
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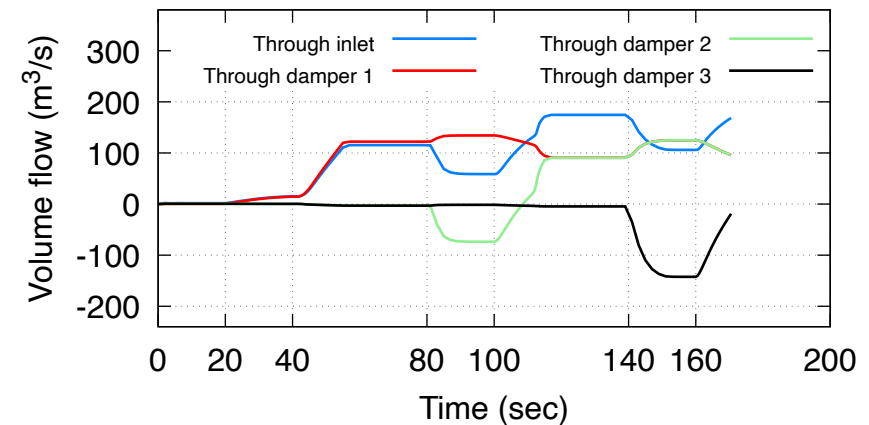
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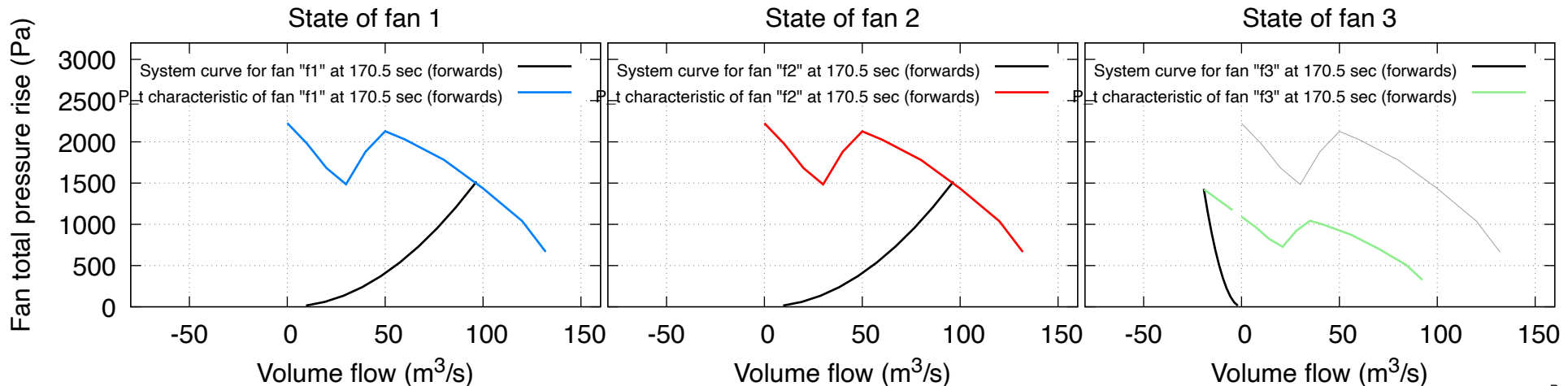
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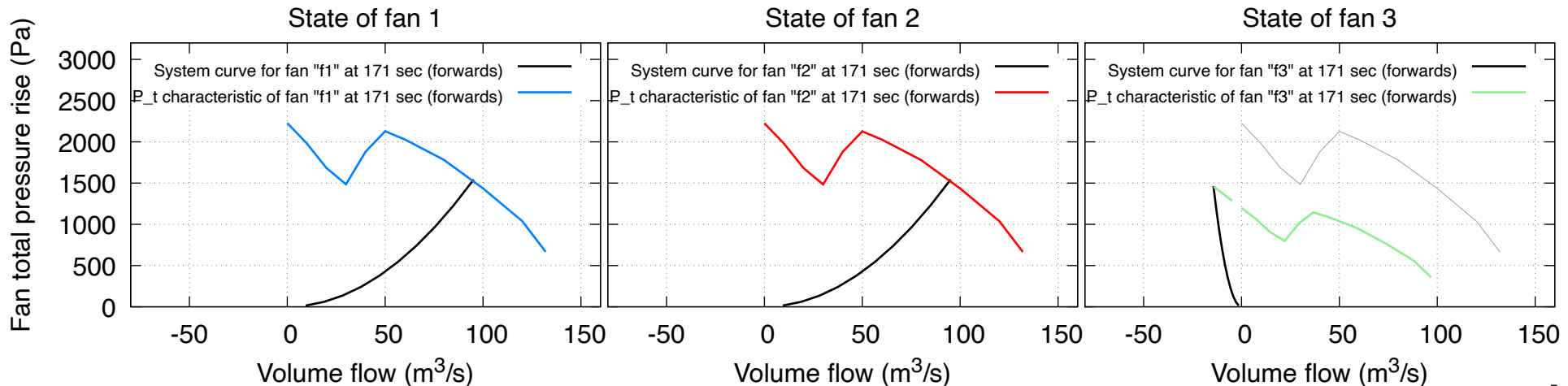
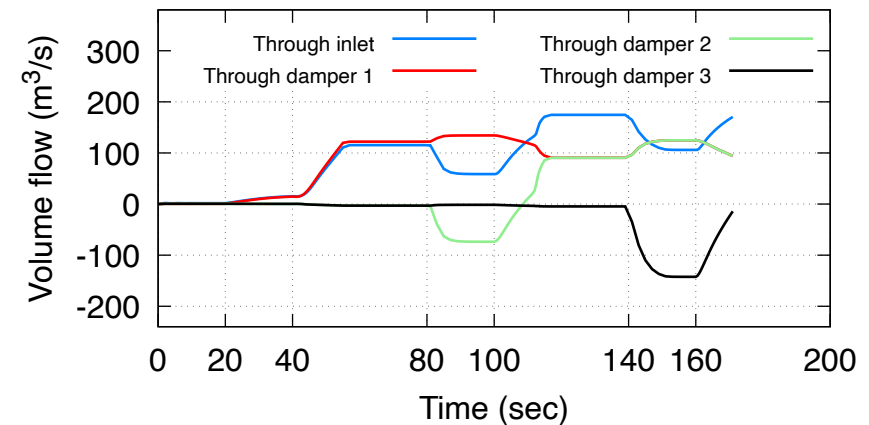
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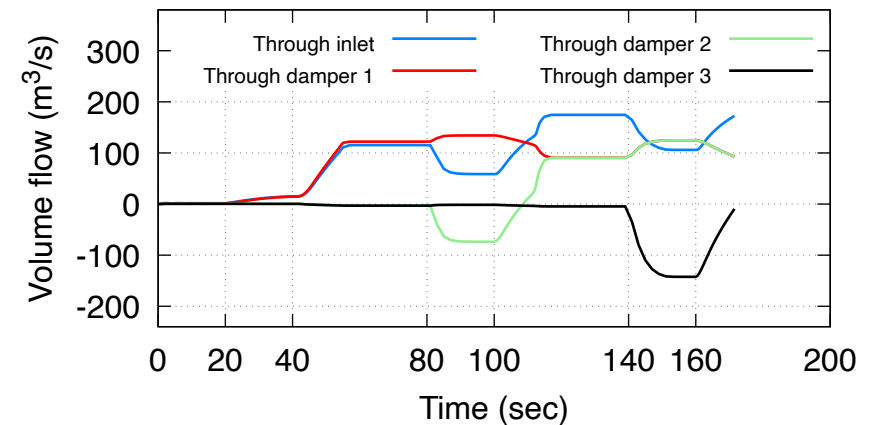
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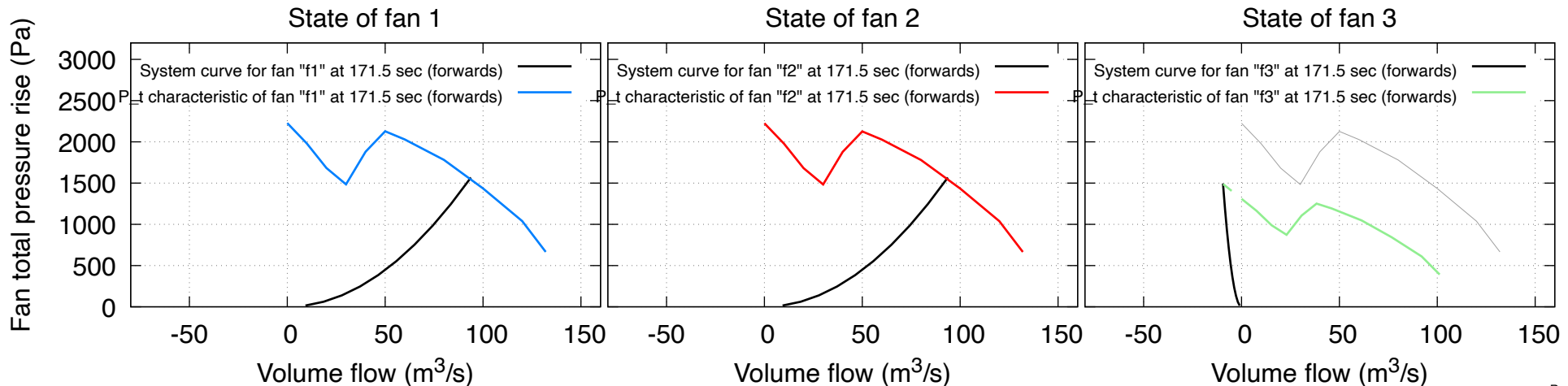
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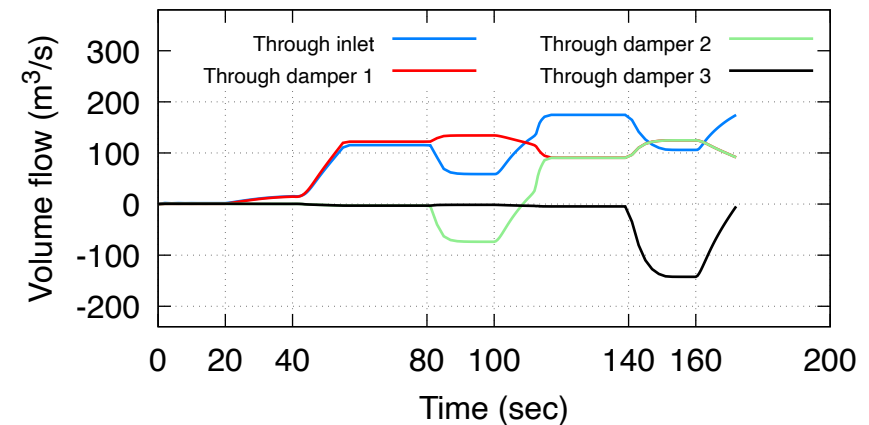
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At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

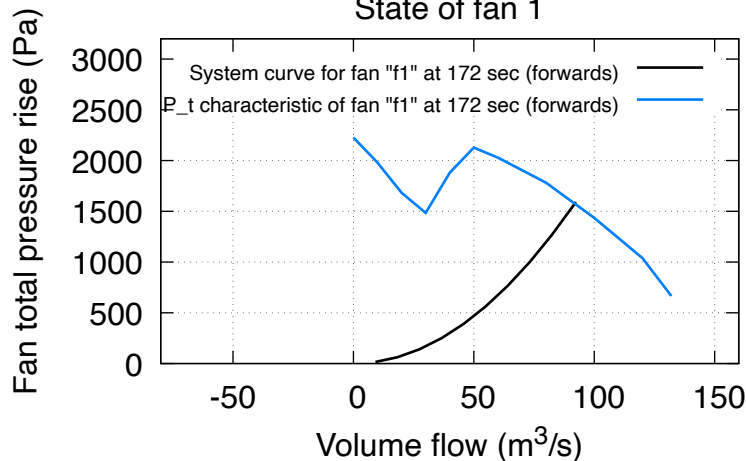
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

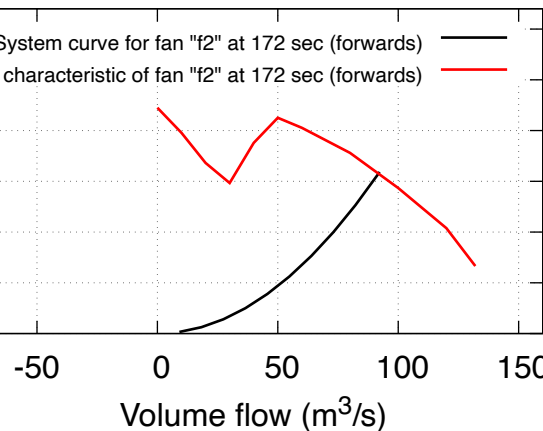
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

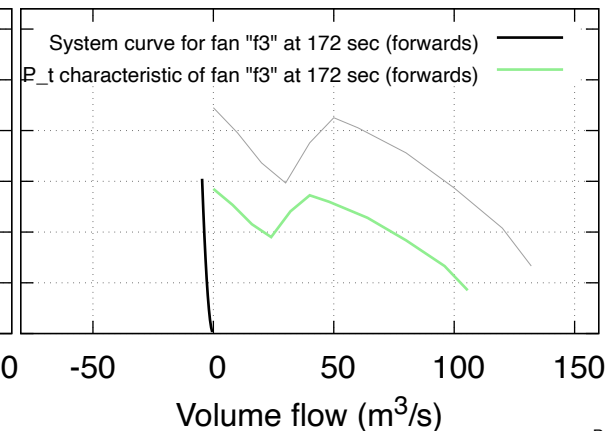
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

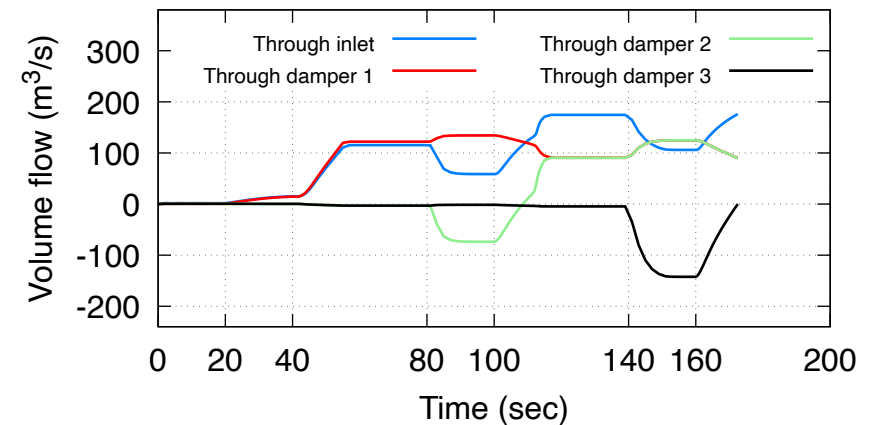
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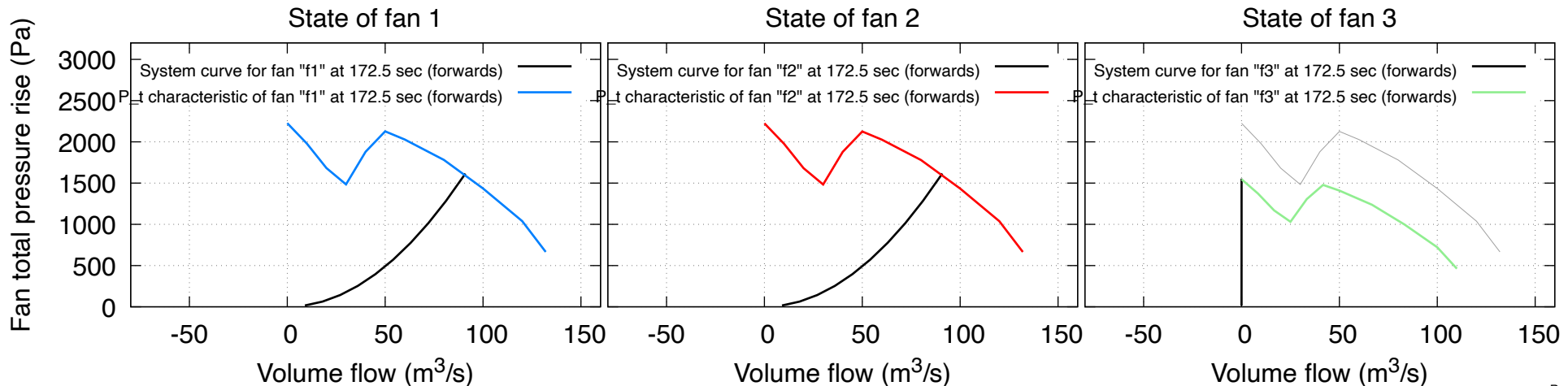
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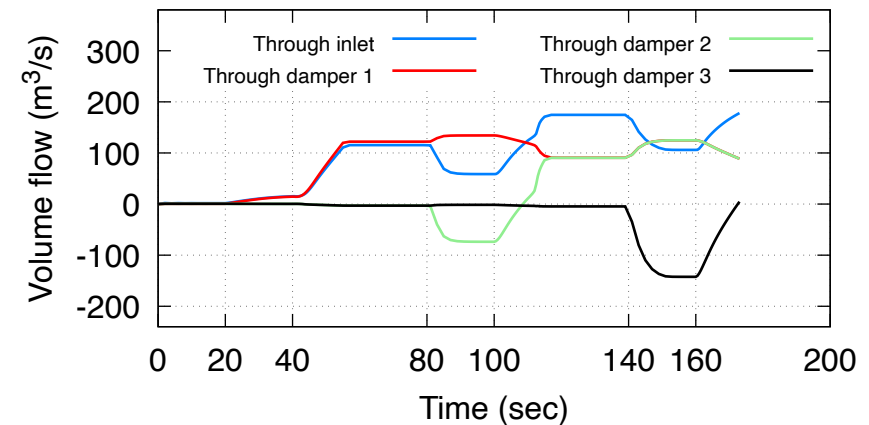
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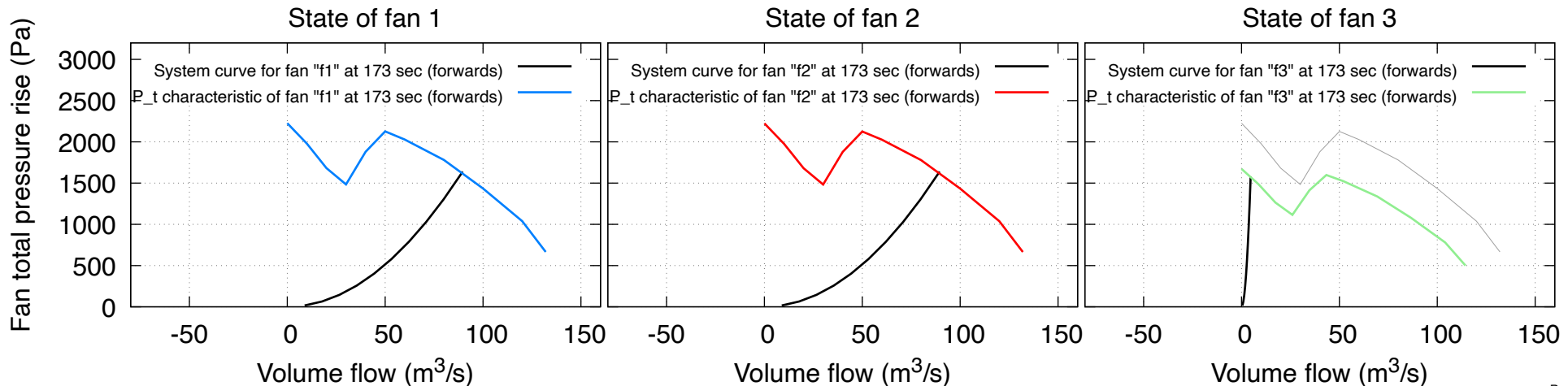
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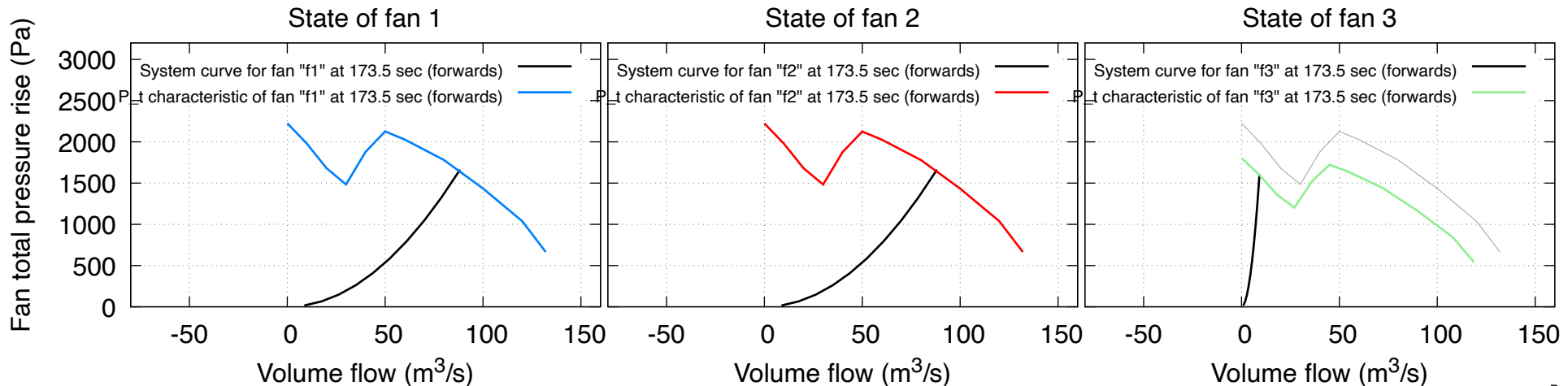
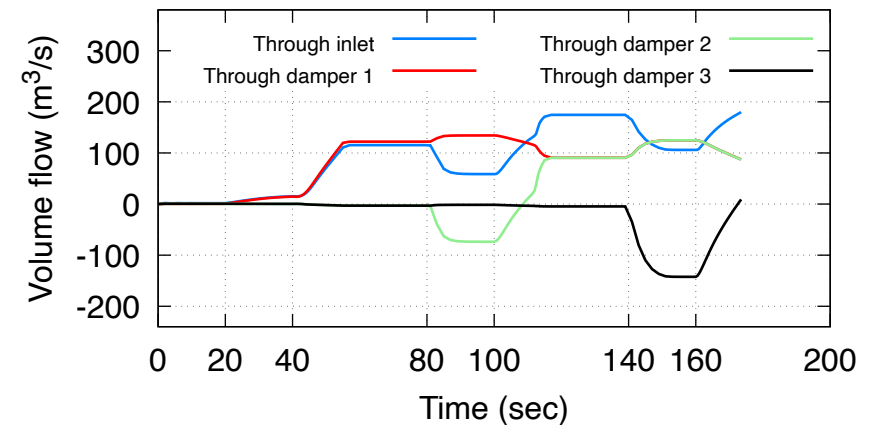
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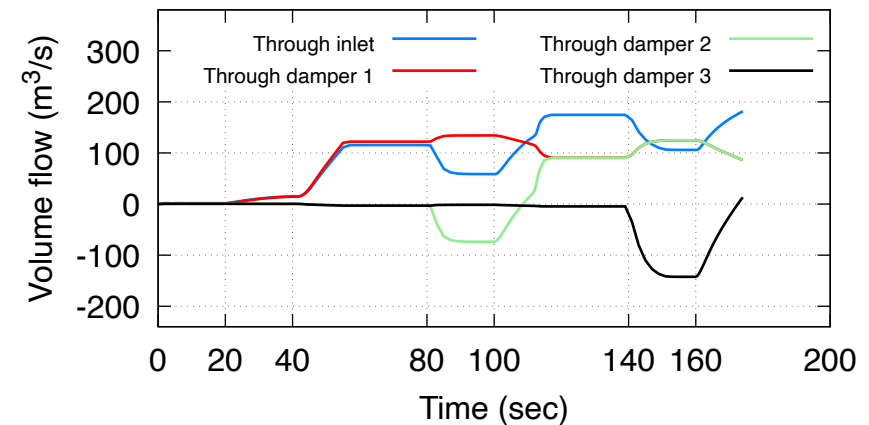
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The fans are started sequentially. Fans 1 and 2 get to suitable parts of their characteristics. Fan 3 can't get out of stall.



Transient volume flows in the system



At 20 seconds, damper 1 opens

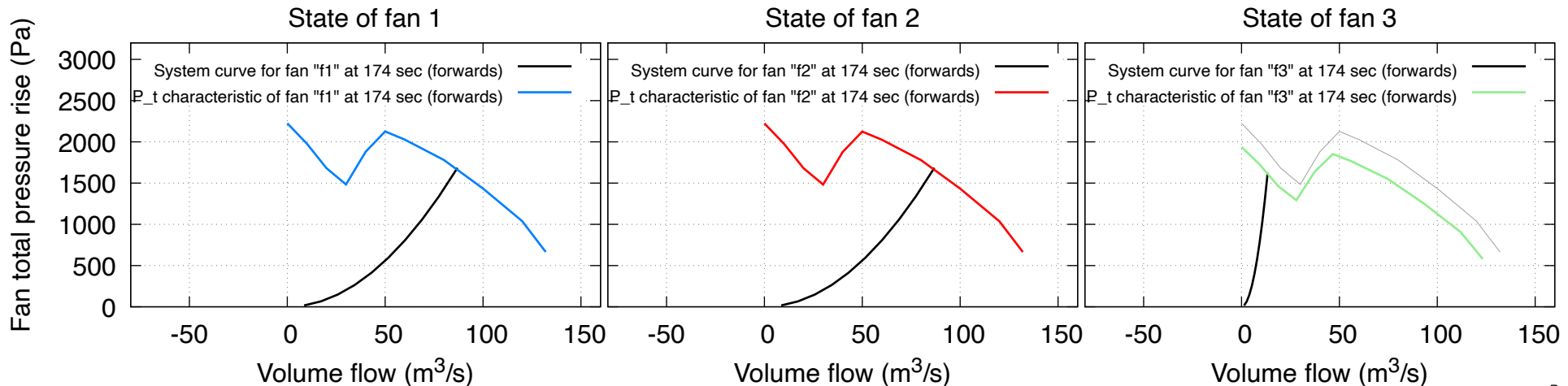
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

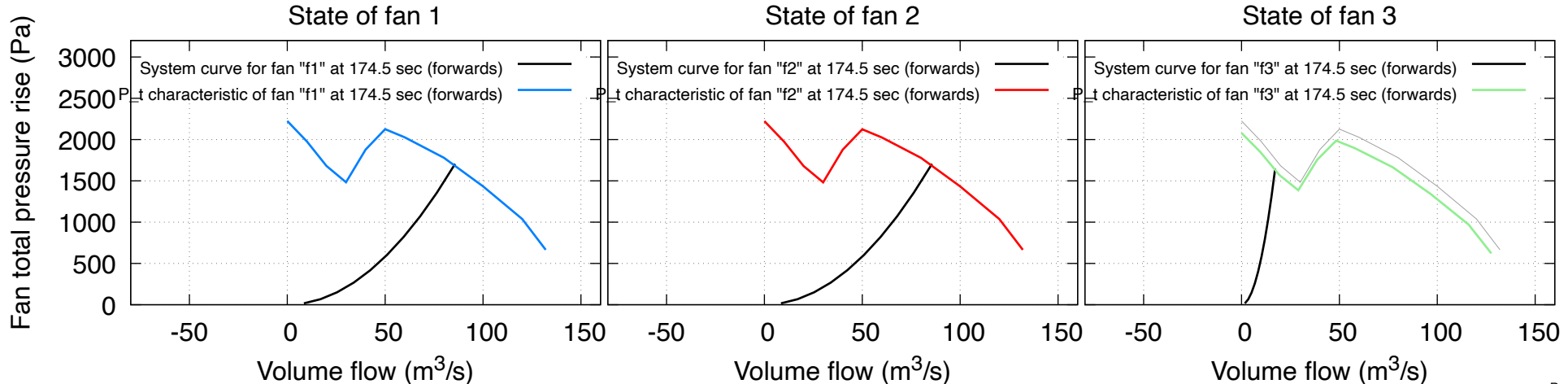
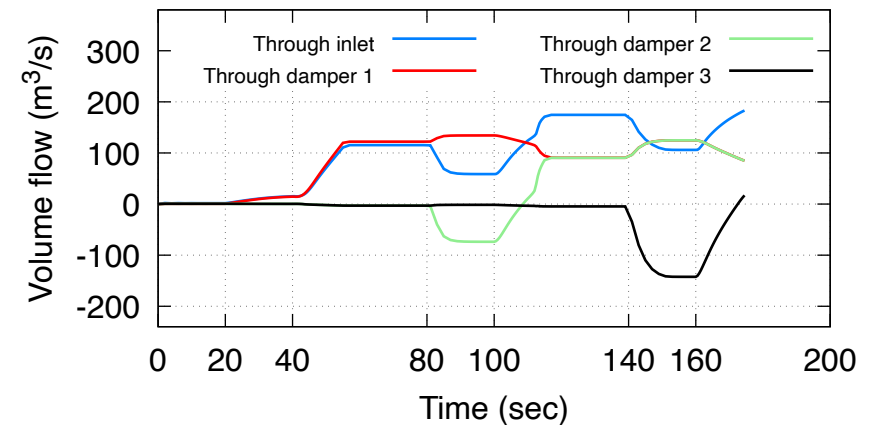
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Transient volume flows in the system



How not to run fans in parallel

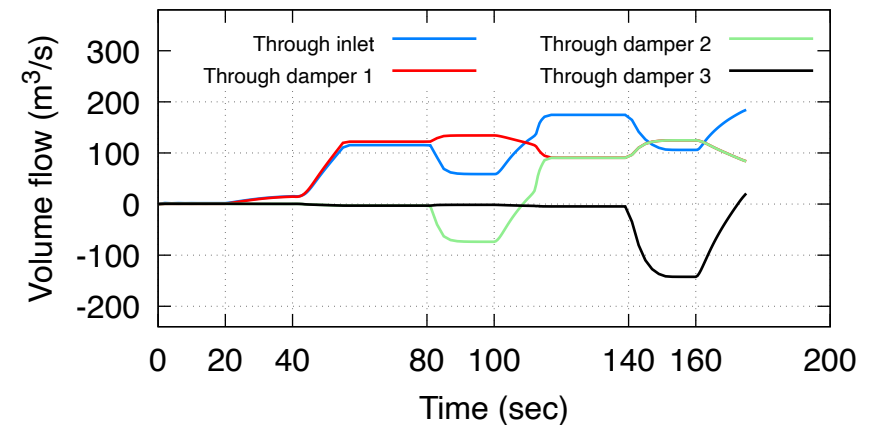
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Transient volume flows in the system



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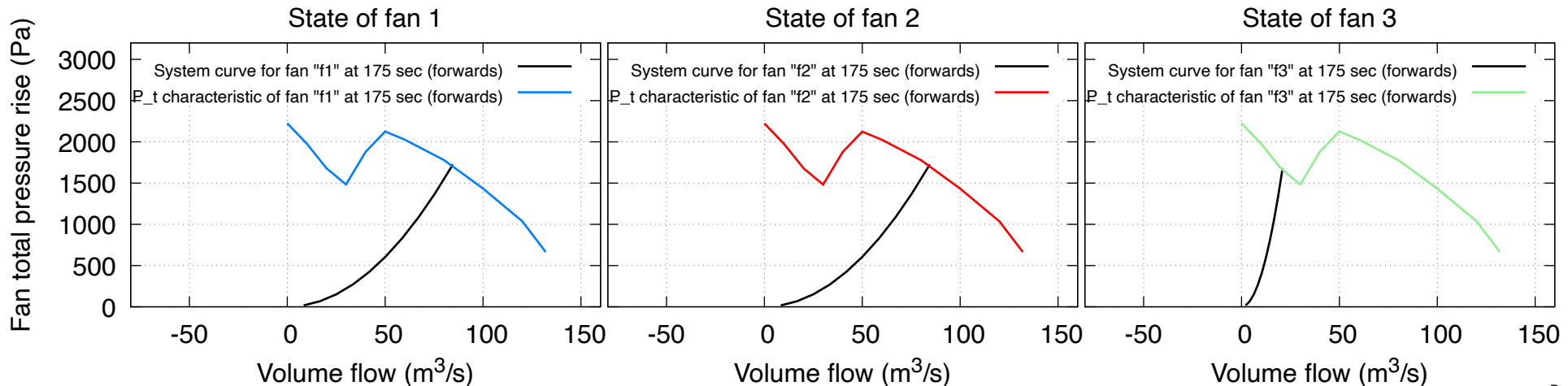
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

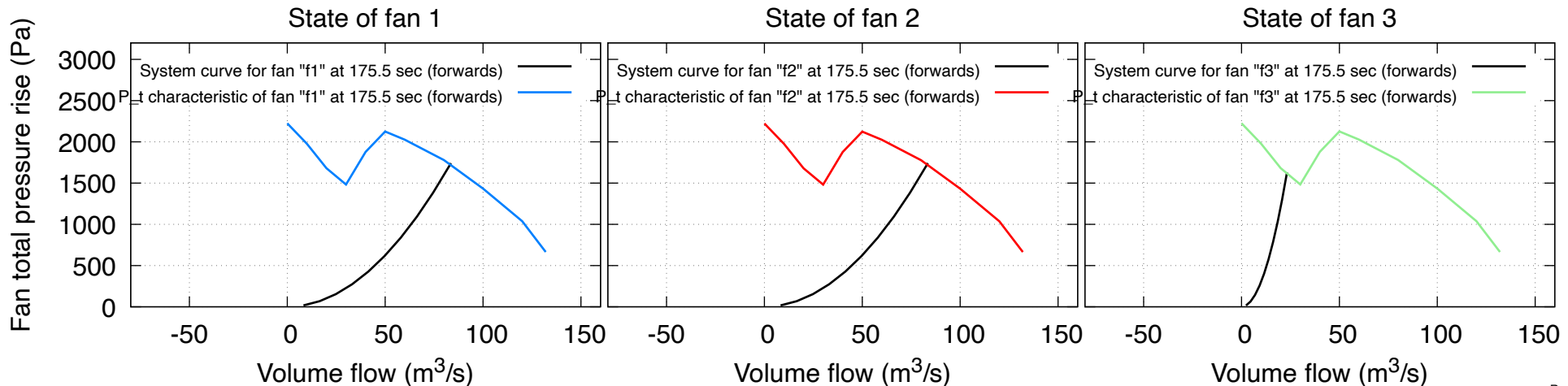
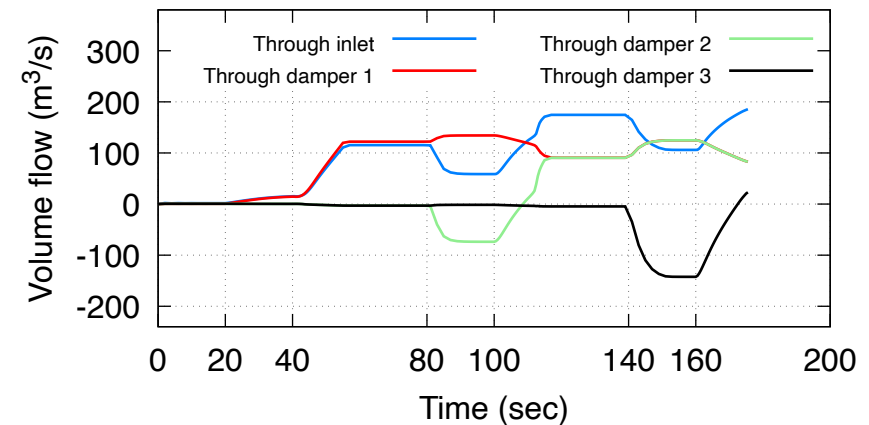
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Transient volume flows in the system



How not to run fans in parallel

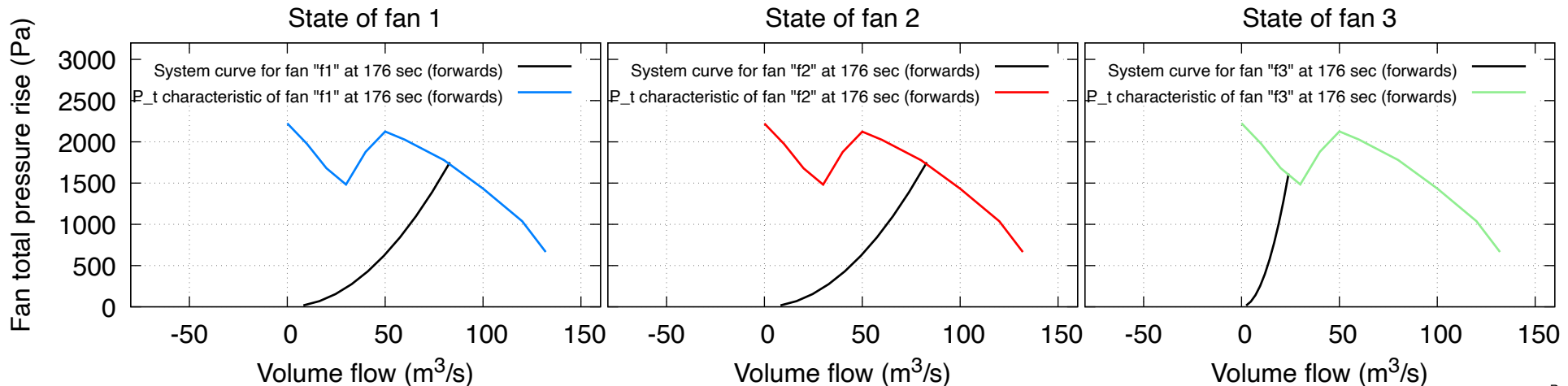
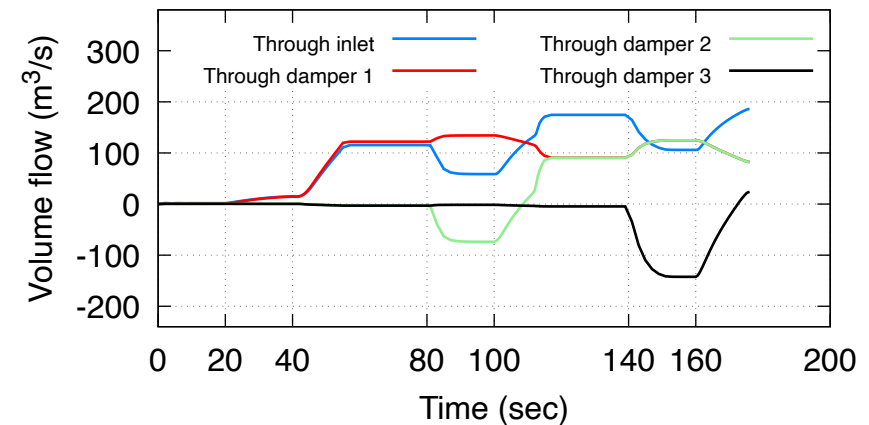
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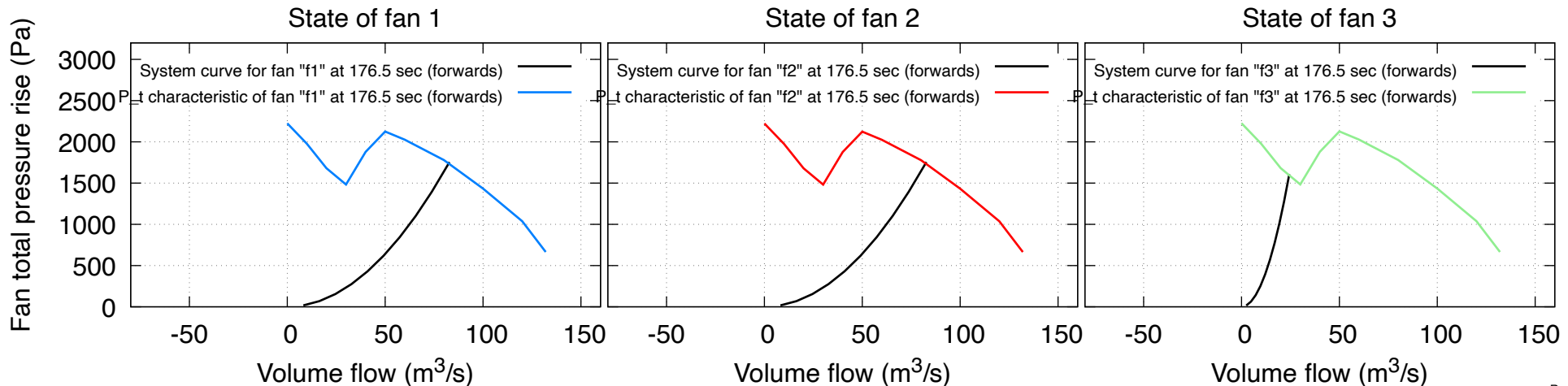
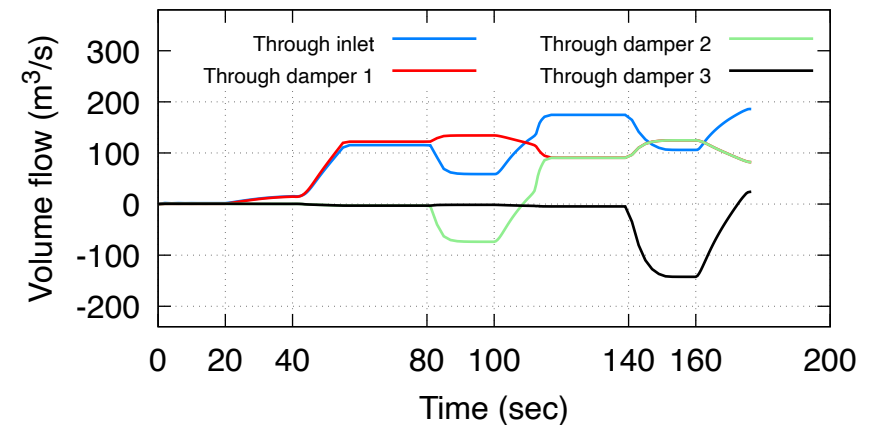
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Transient volume flows in the system



How not to run fans in parallel

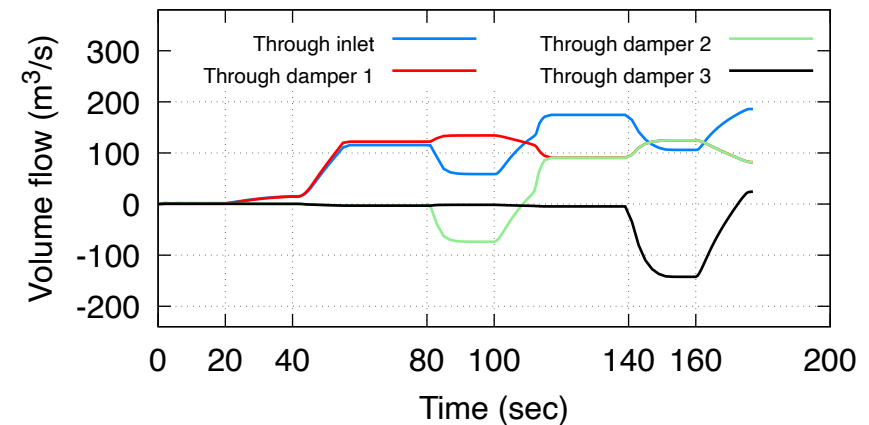
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

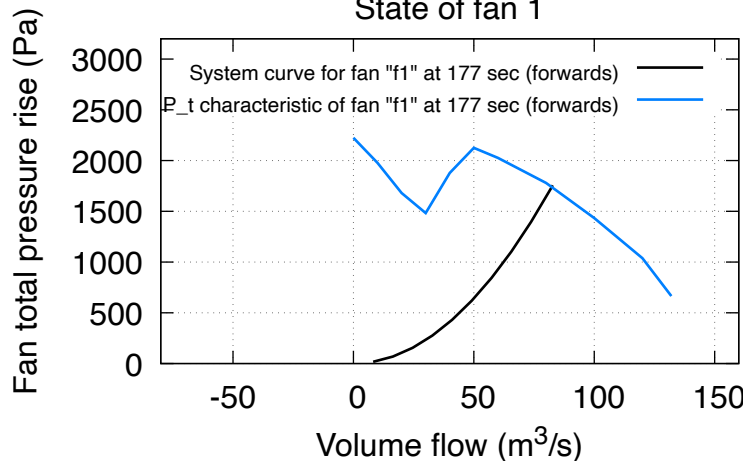
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

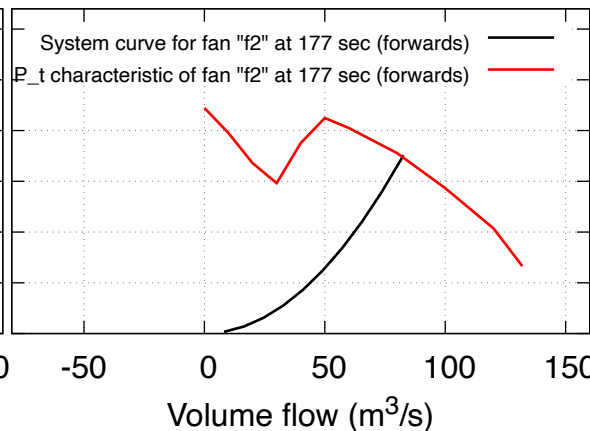
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

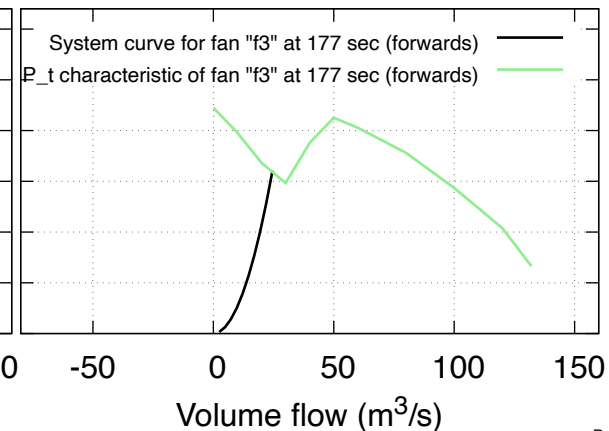
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

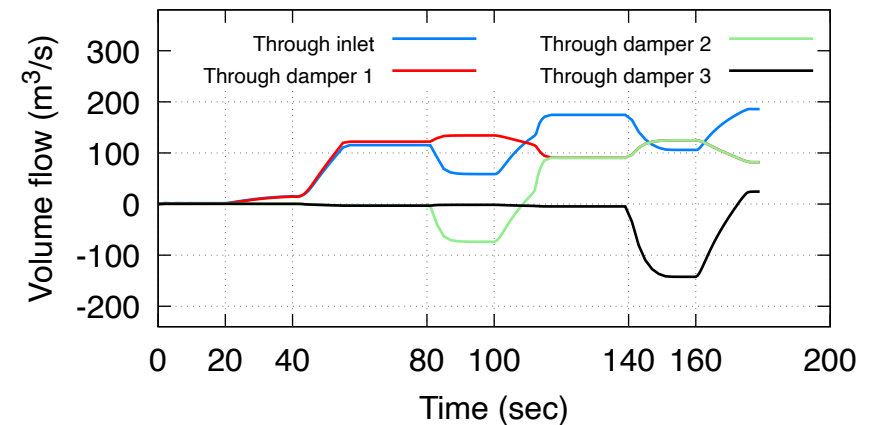
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Transient volume flows in the system



At 20 seconds, damper 1 opens

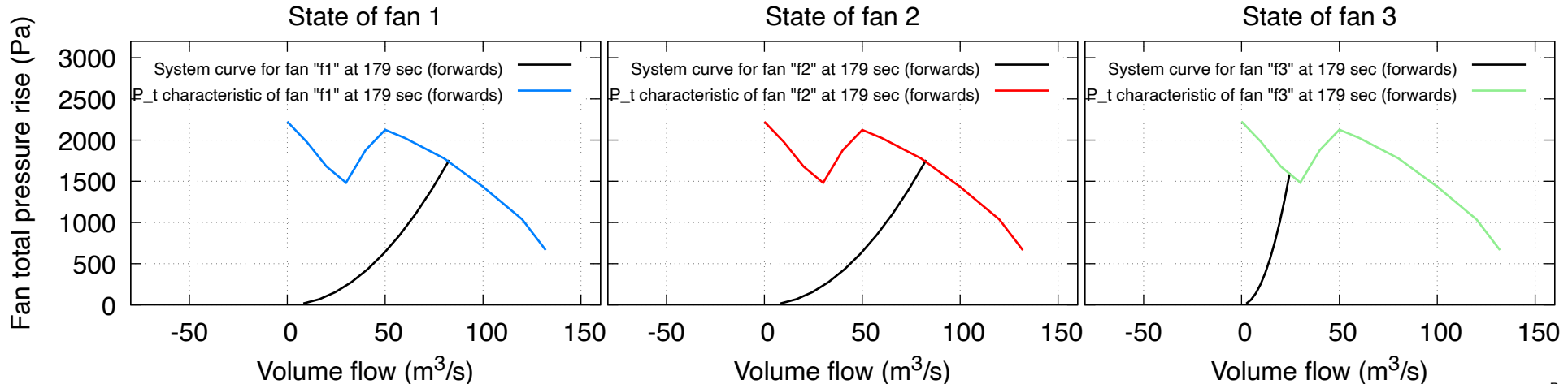
At 40 seconds, fan 1 starts

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How not to run fans in parallel

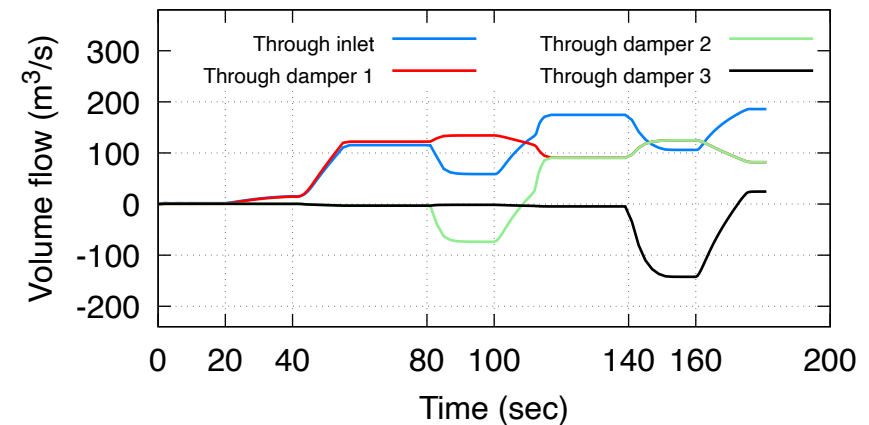
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Transient volume flows in the system



At 20 seconds, damper 1 opens

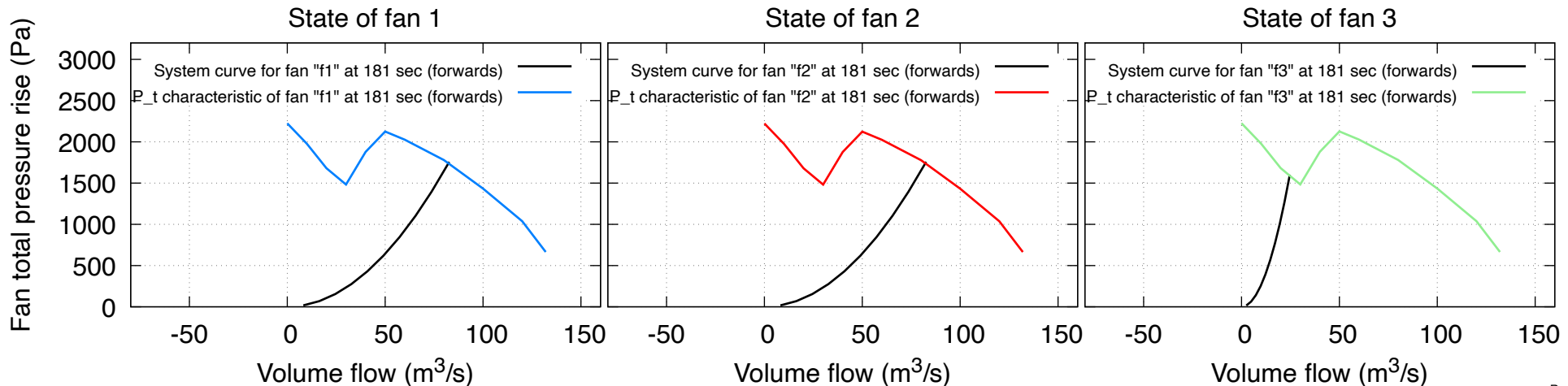
At 40 seconds, fan 1 starts

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At 160 seconds, fan 3 starts



How not to run fans in parallel

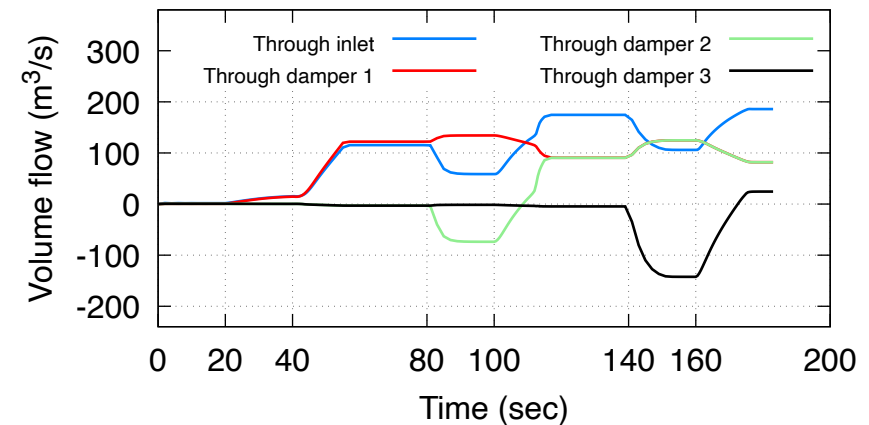
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Transient volume flows in the system



At 20 seconds, damper 1 opens

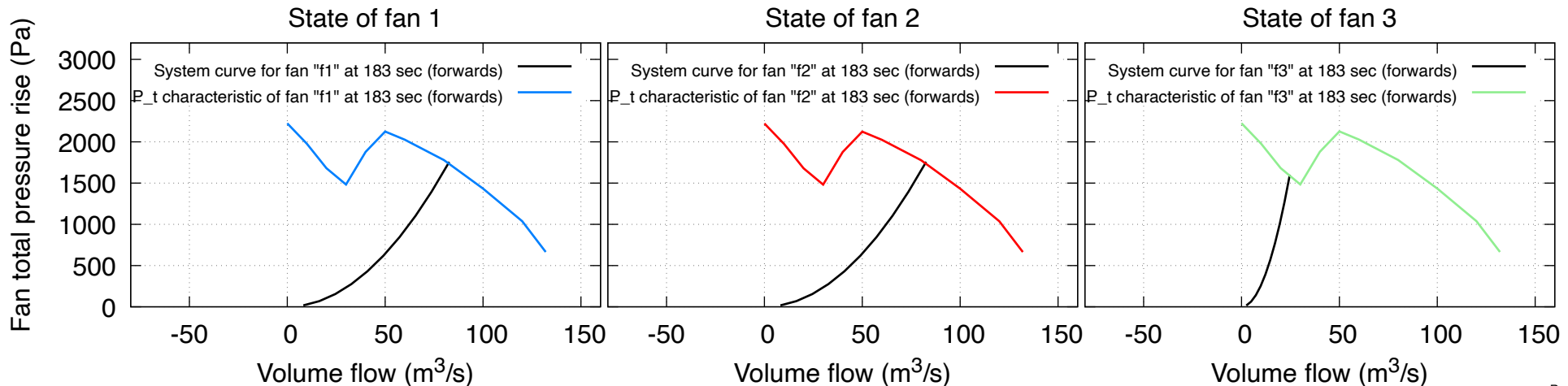
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

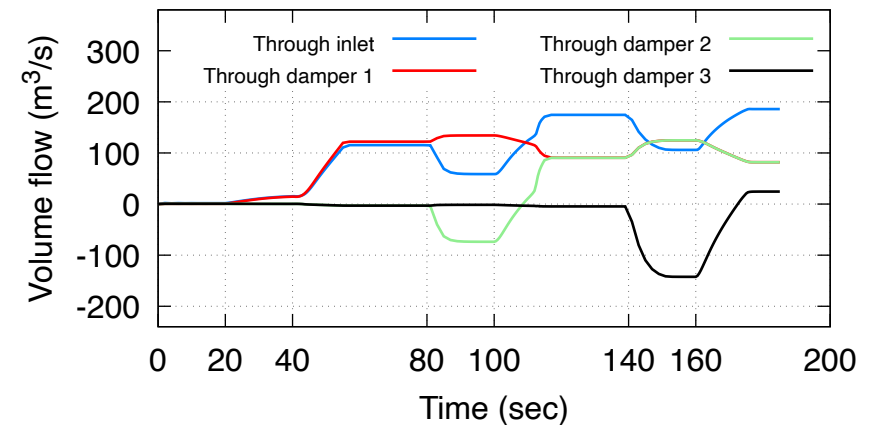
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Transient volume flows in the system



At 20 seconds, damper 1 opens

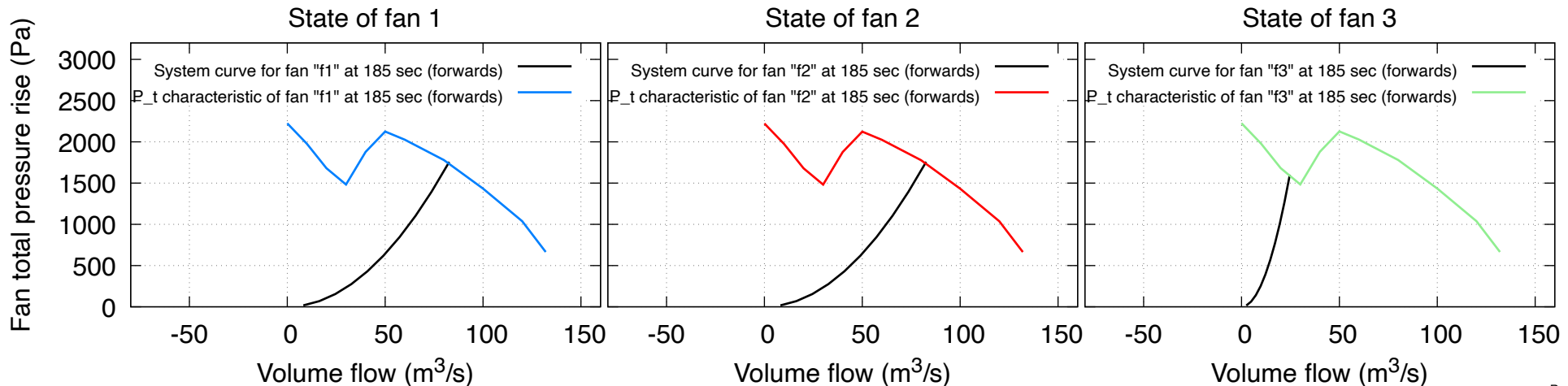
At 40 seconds, fan 1 starts

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At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

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How not to run fans in parallel

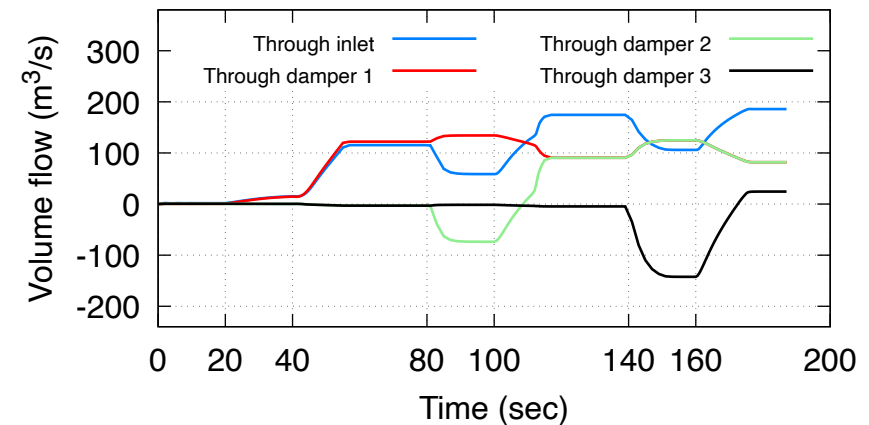
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

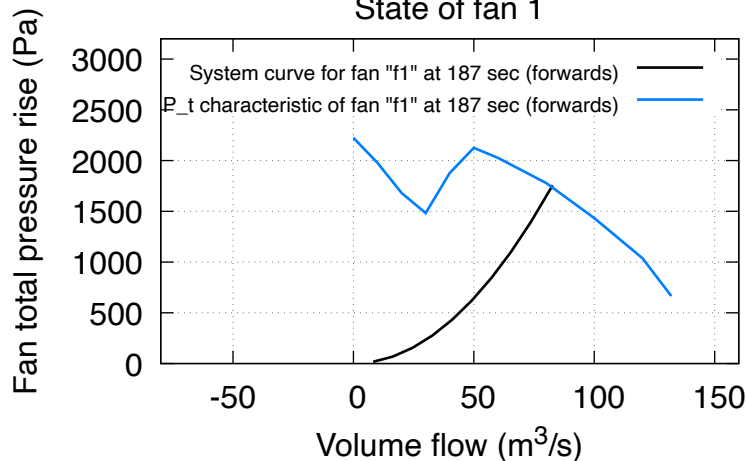
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

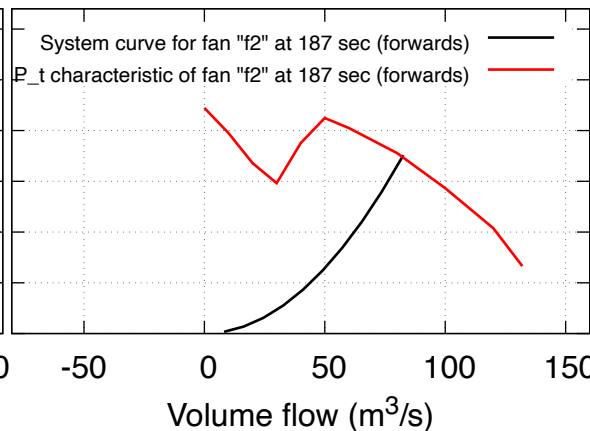
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

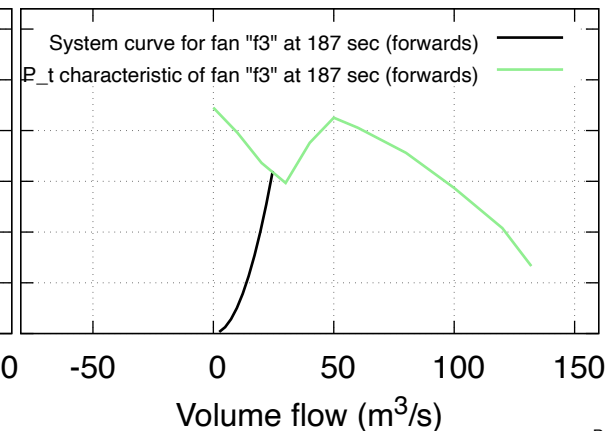
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

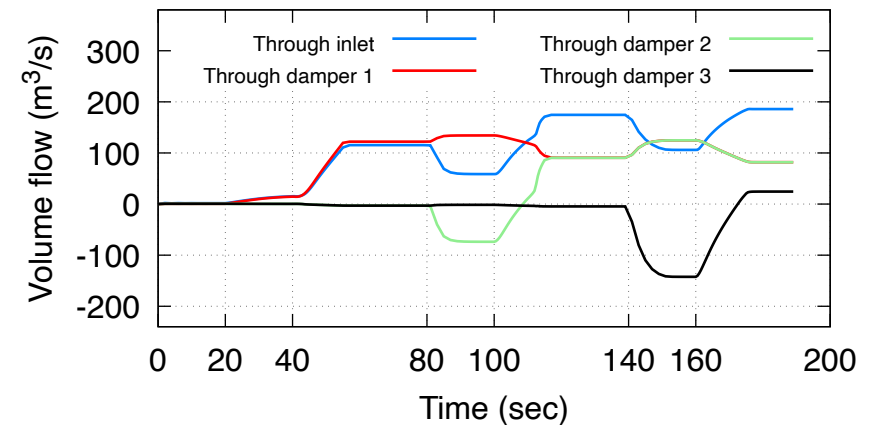
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Transient volume flows in the system



At 20 seconds, damper 1 opens

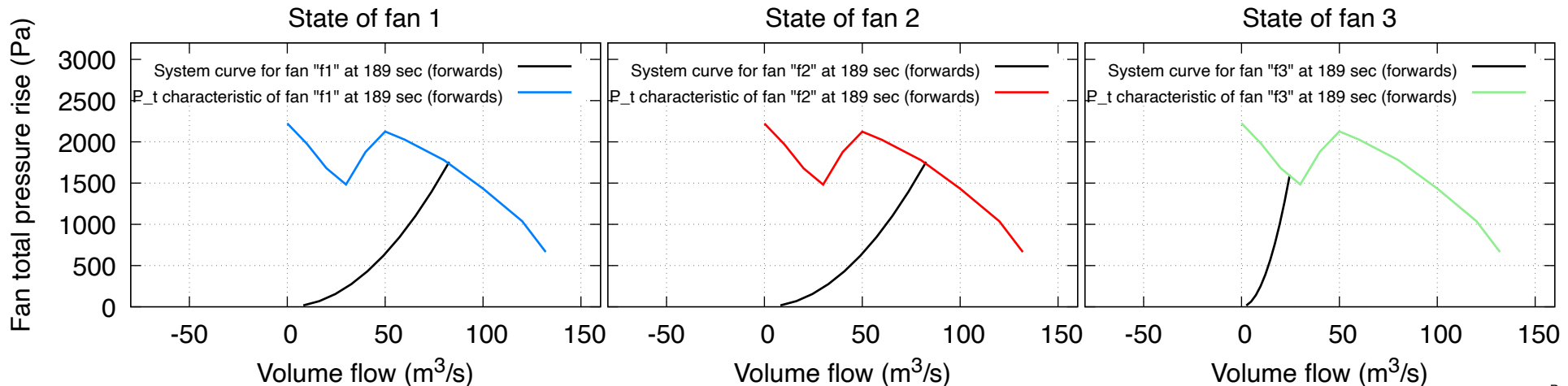
At 40 seconds, fan 1 starts

At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

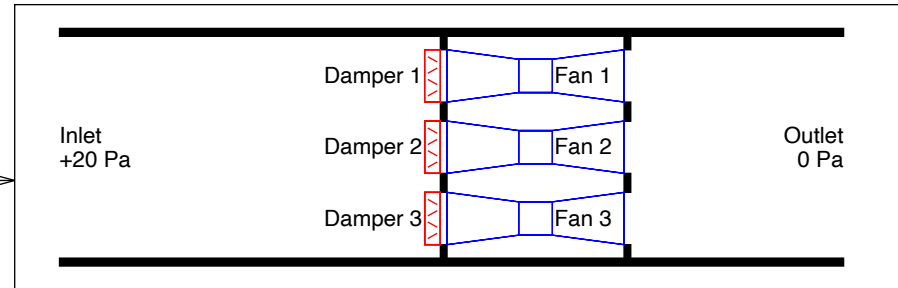


How not to run fans in parallel

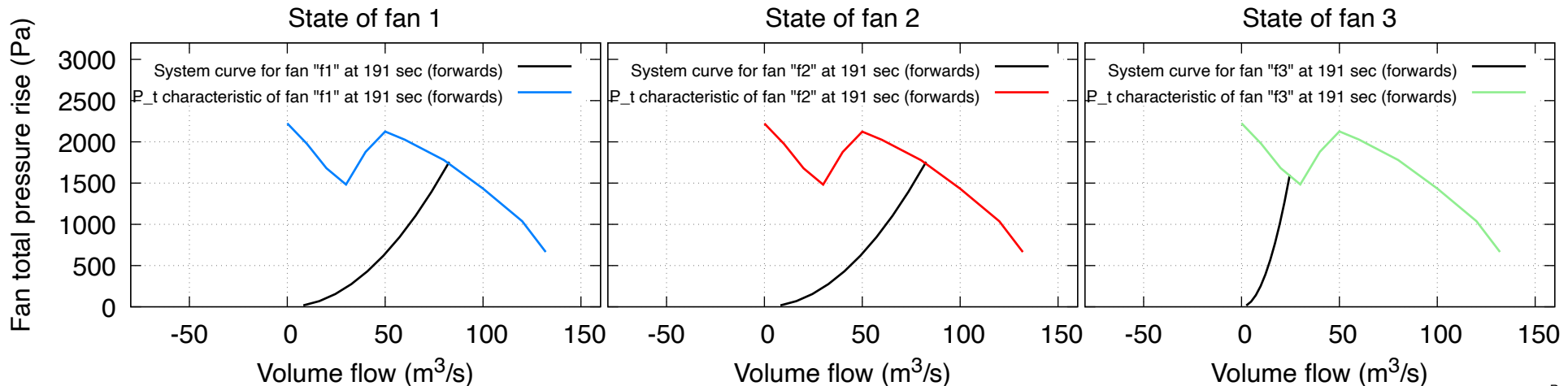
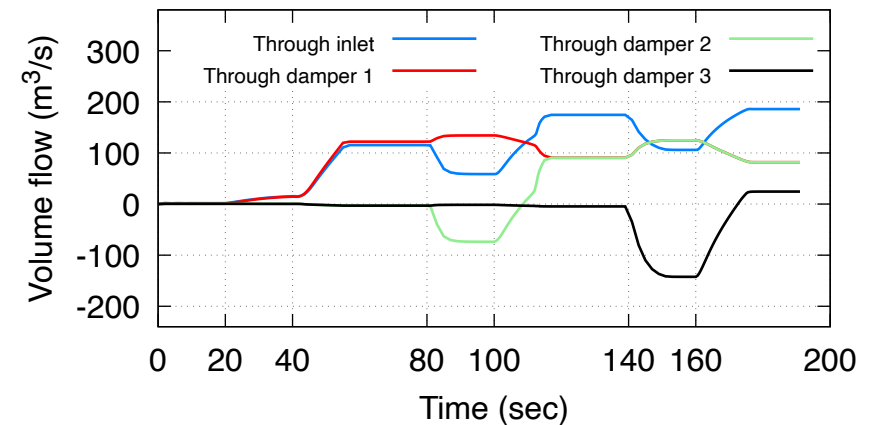
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Transient volume flows in the system



How not to run fans in parallel

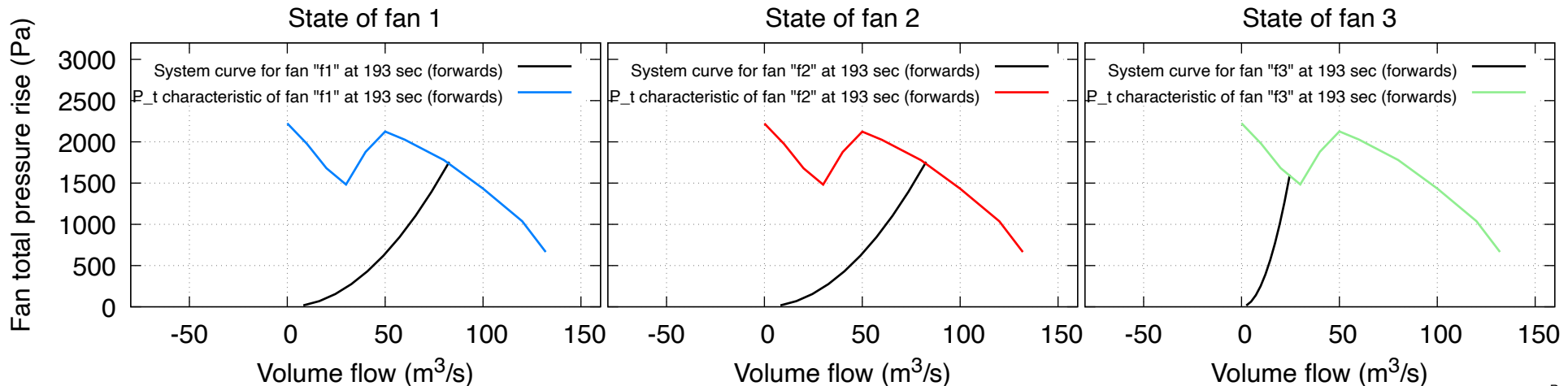
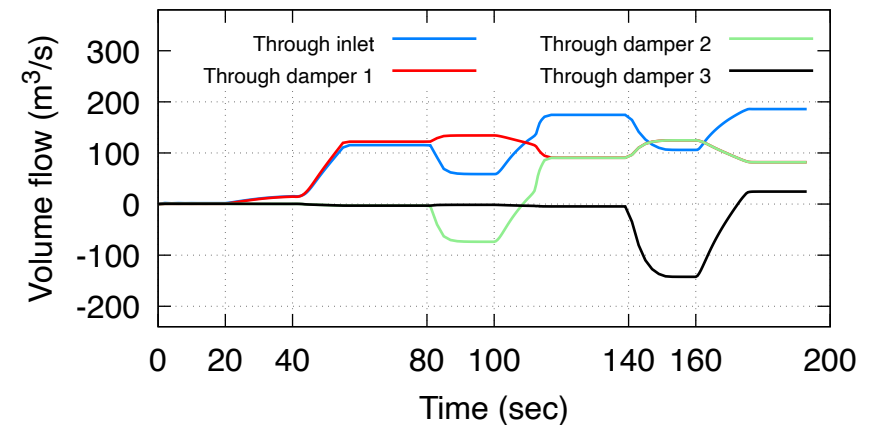
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Transient volume flows in the system



How not to run fans in parallel

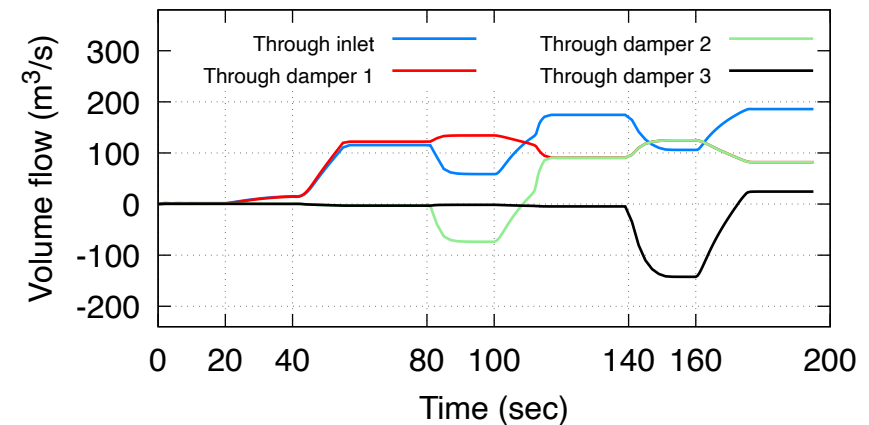
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Transient volume flows in the system



At 20 seconds, damper 1 opens

At 40 seconds, fan 1 starts

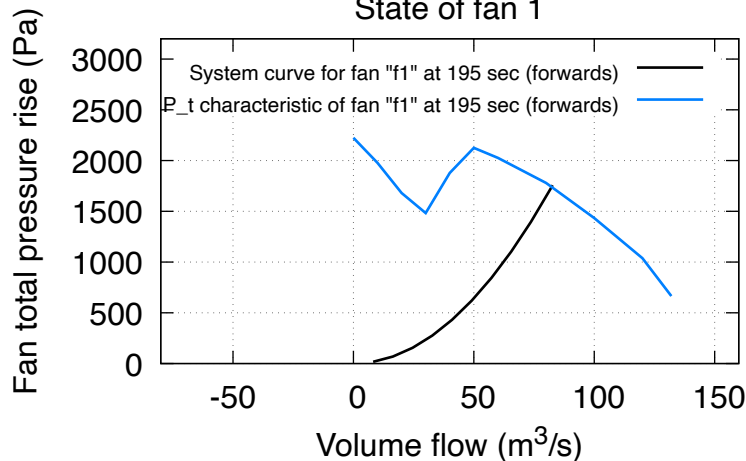
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

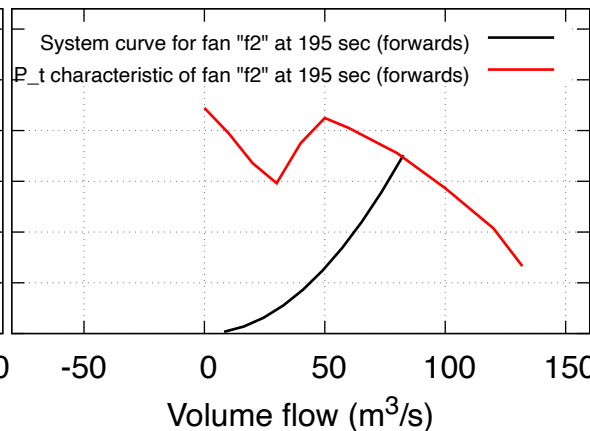
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

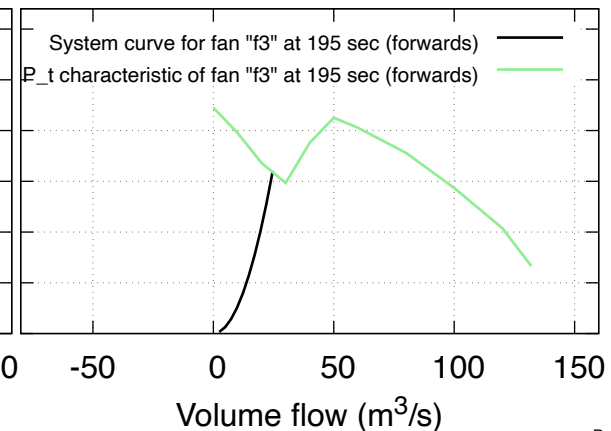
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

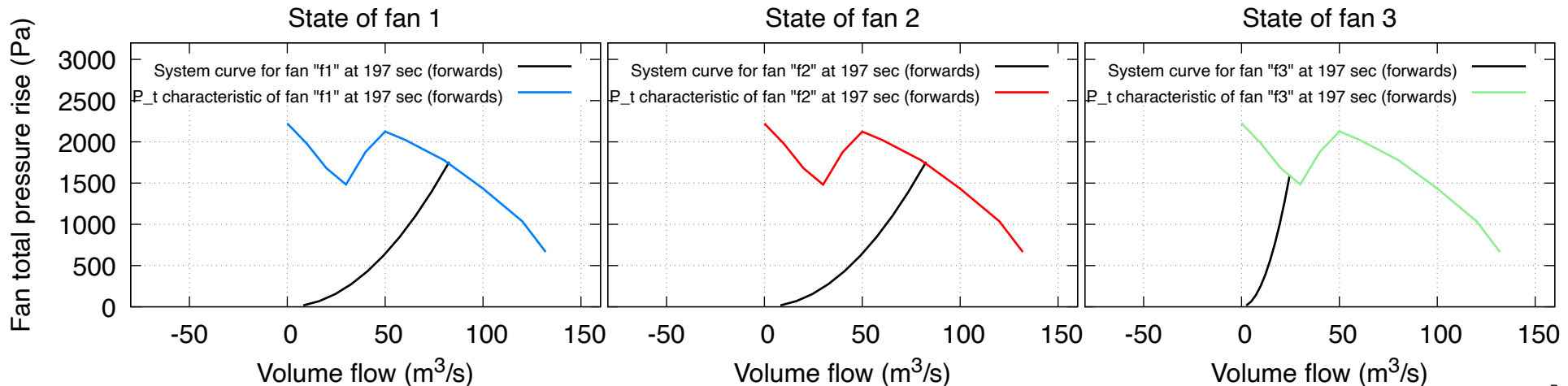
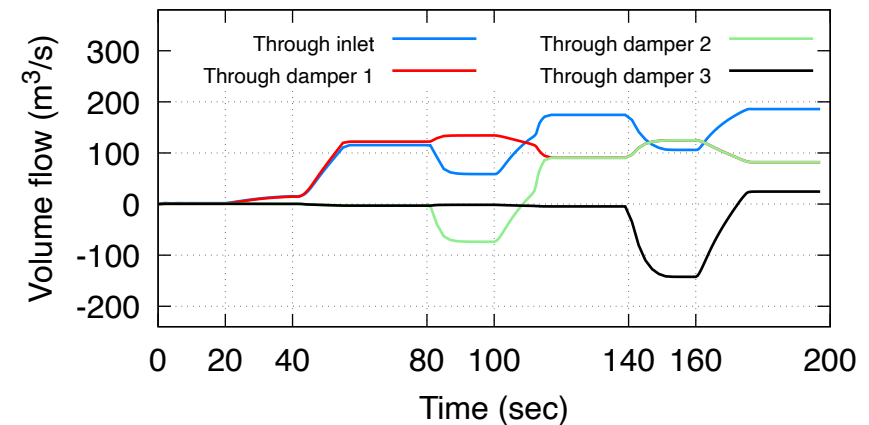
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Transient volume flows in the system



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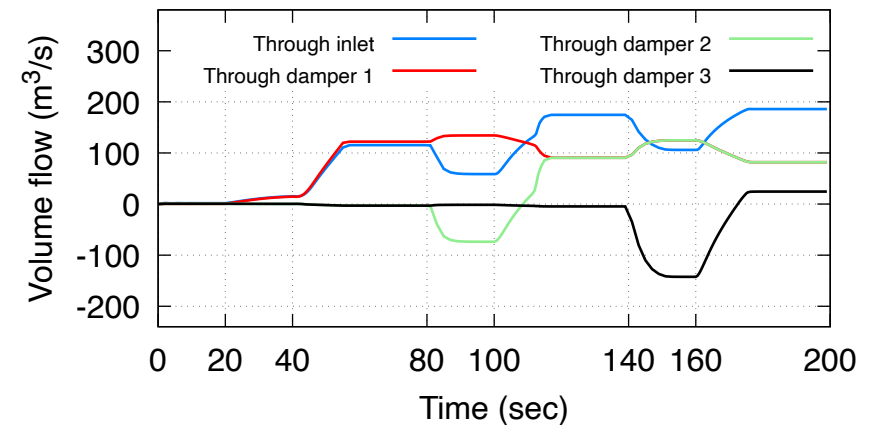
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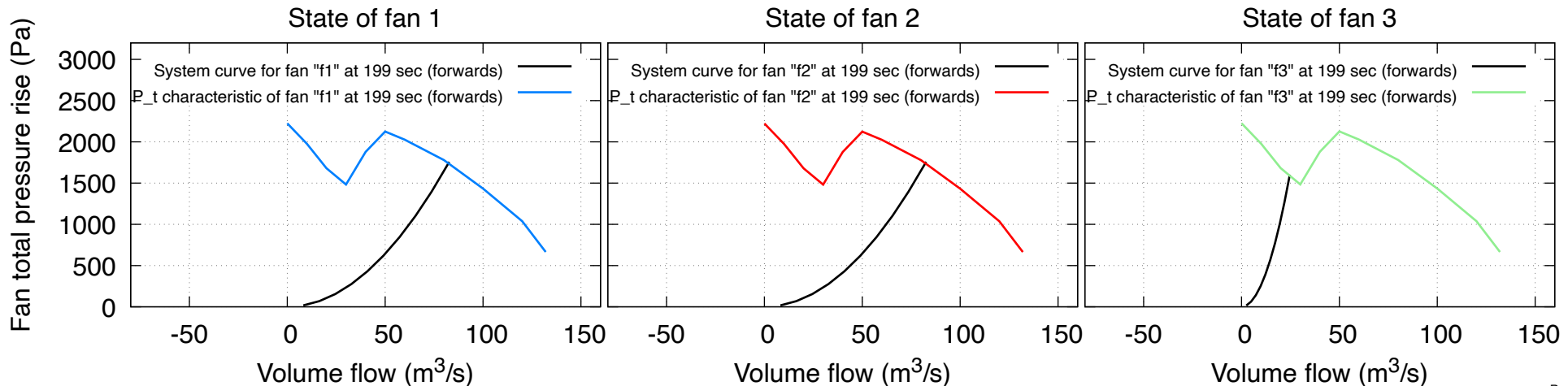
At 40 seconds, fan 1 starts

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At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts



How not to run fans in parallel

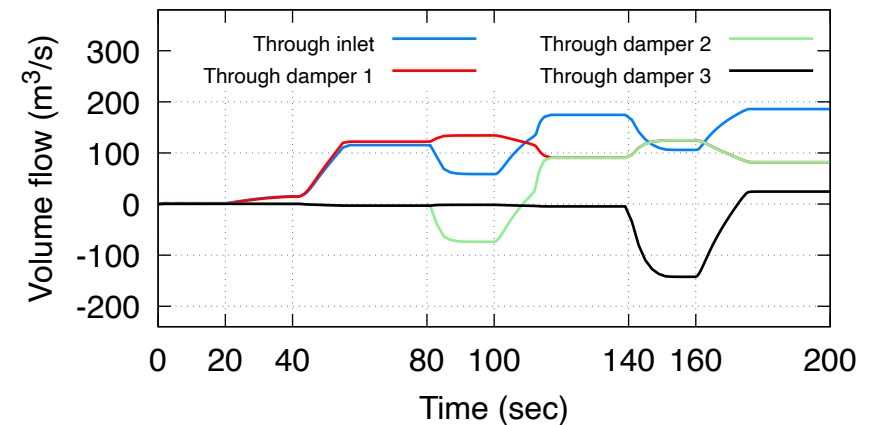
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Transient volume flows in the system



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At 40 seconds, fan 1 starts

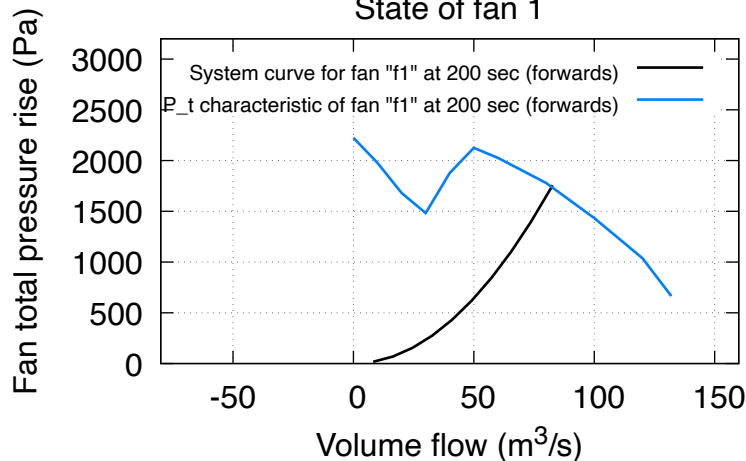
At 80 seconds, damper 2 opens

At 100 seconds, fan 2 starts

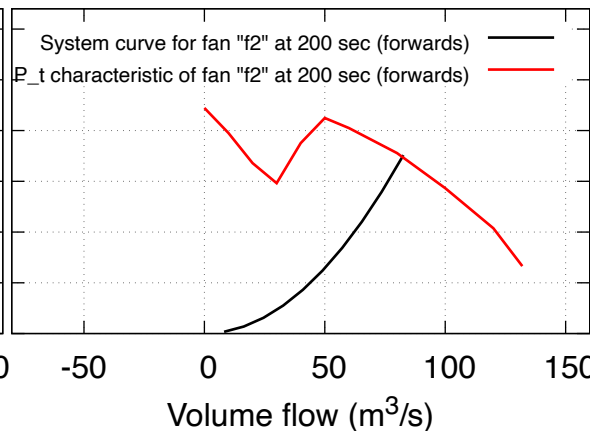
At 140 seconds, damper 3 opens

At 160 seconds, fan 3 starts

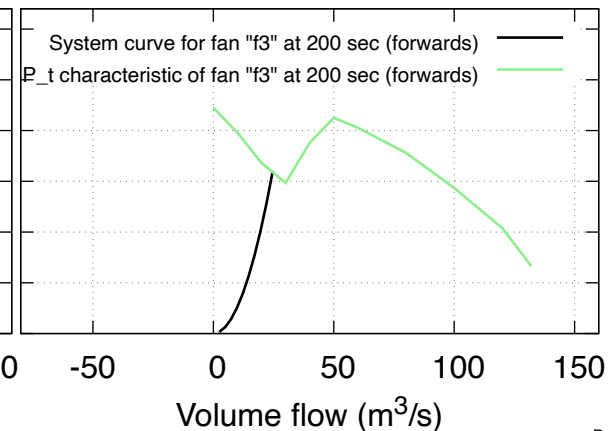
State of fan 1



State of fan 2



State of fan 3



How not to run fans in parallel

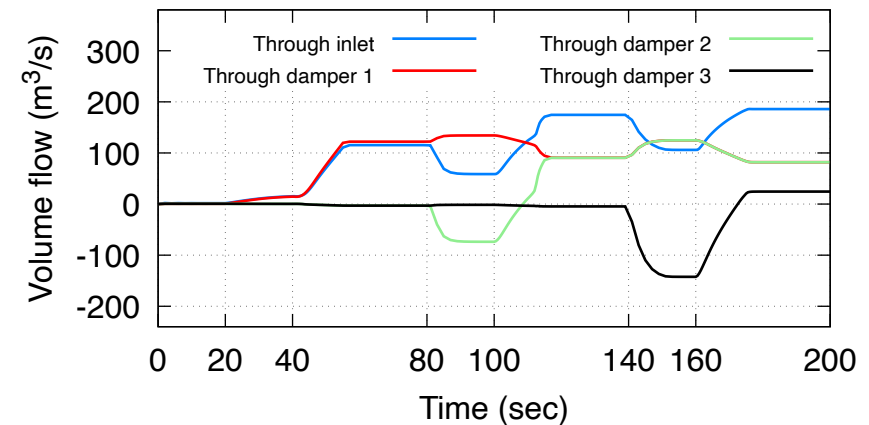
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