

Waipori 1 Power Station



Waipori 2 Power Station



Waipori 3 Power Station



Waipori 4 Power Station



Development of Models for Hydro Power Plants with Shared Penstock for Grid Compliance Study

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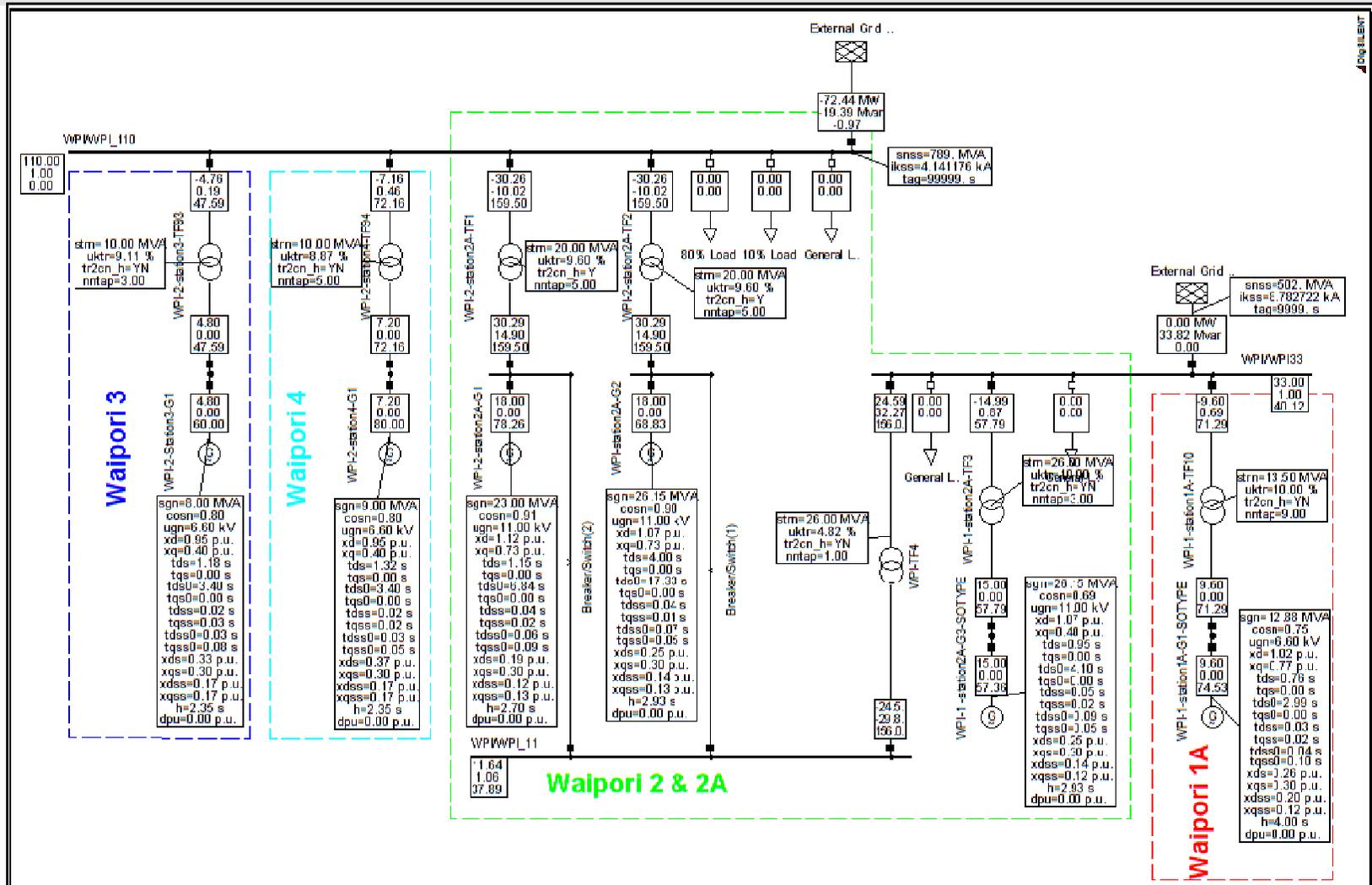


Introduction

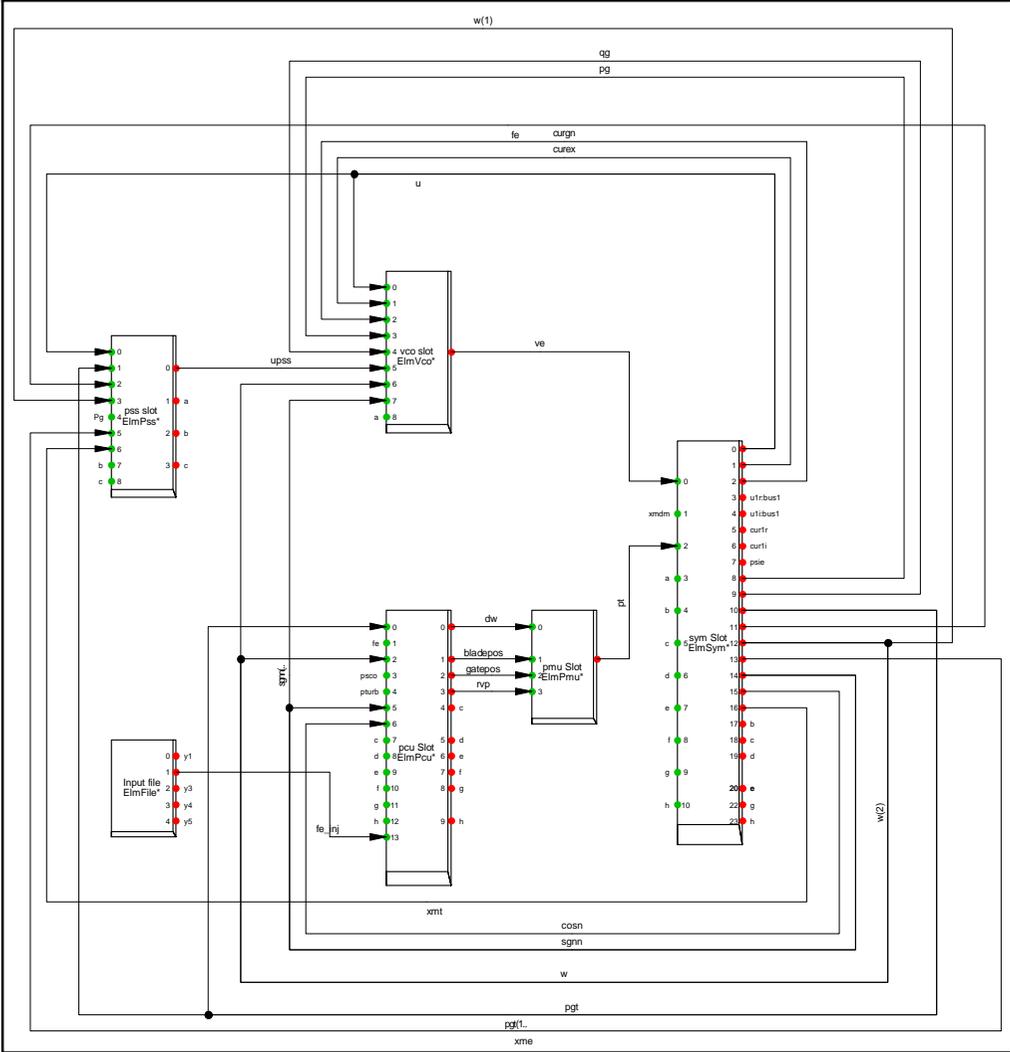
- The Waipori River is located about 64 km to the west of Dunedin, rising in the Lammerlaw Mountains. After winding through a course of about 24 km the River emerges into a valley 1.5 km wide and 27 km long, with a drop of only 30-metres. Following the first steps towards generating electricity from the Waipori River in May 1900, on 27th April 1907 the Waipori Hydro-Electric Power Station was commissioned. This hydro scheme consists of four generation stations as follows:
- Station 1A (separate penstock): Unit G1A: 12.88 MVA, 0.75pf.
- Station 2A (shared penstock):
 - Unit G2A-1: 23.00MVA, 0.91
 - Unit G2A-2: 26.15MVA, 0.90pf
 - Unit G2A-3: 26.15MVA, 0.69pf
- Station 3 (separate penstock): Unit G3: 8.0MVA, 0.80pf.
- Station 4 (separate penstock): Unit G4: 9.0MVA, 0.80pf.



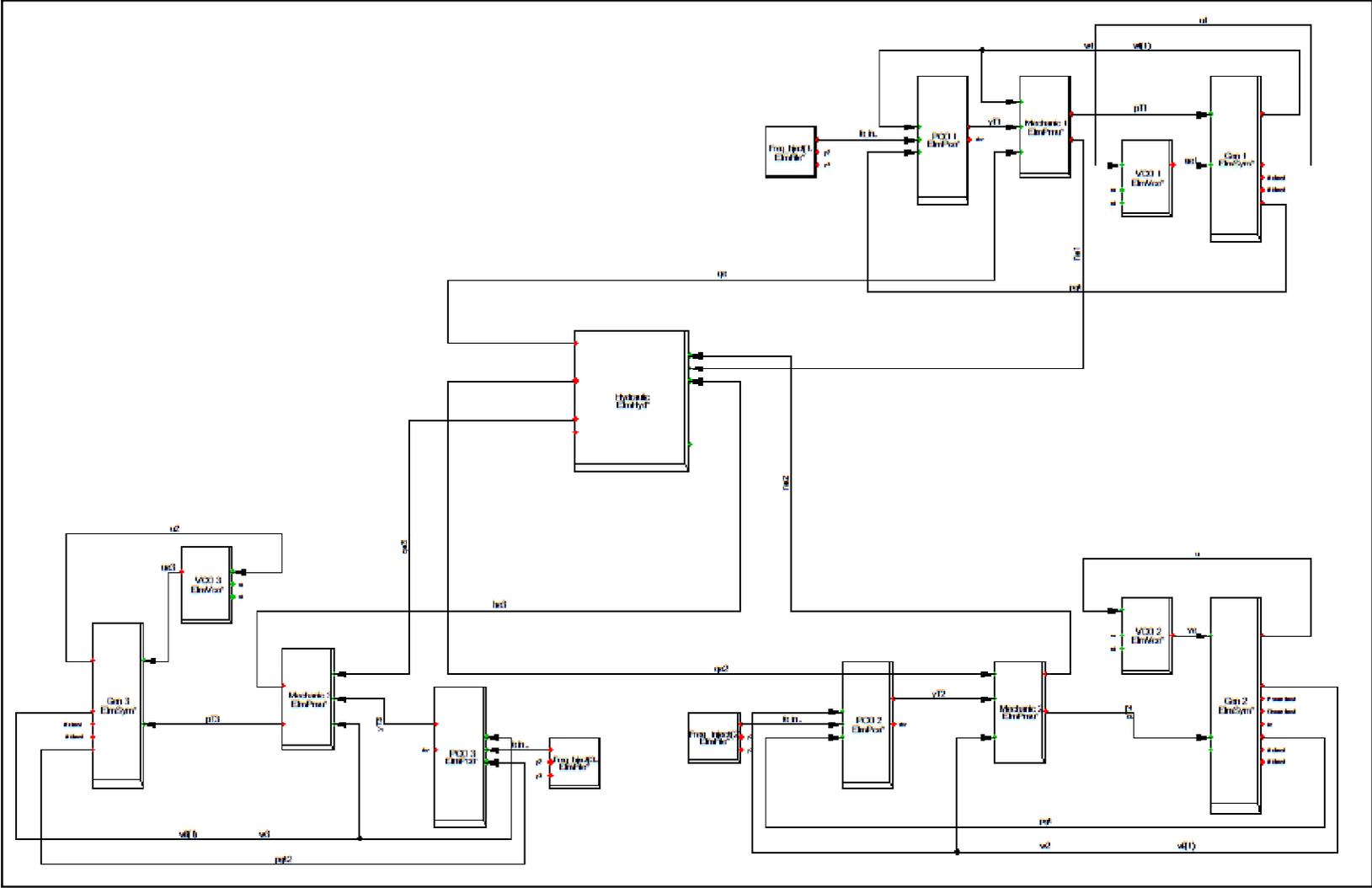
Network Model (DIgSILENT)



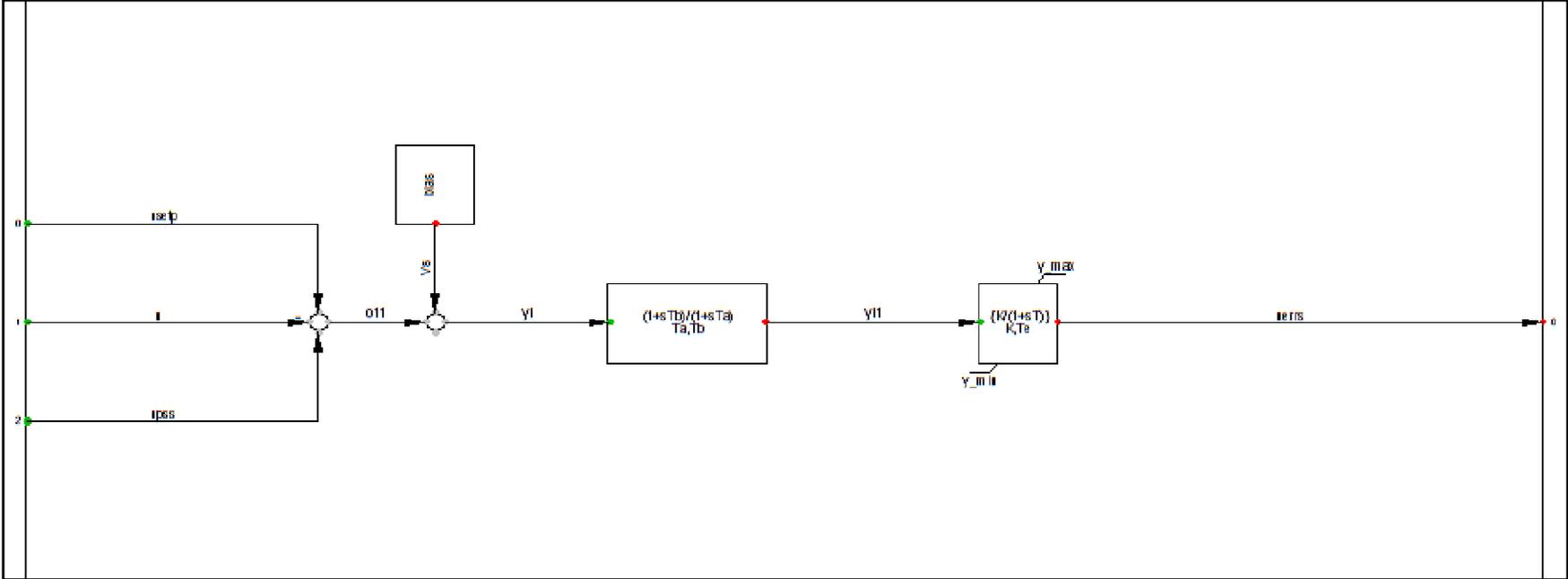
Plant/Frame Model: Separate Penstock



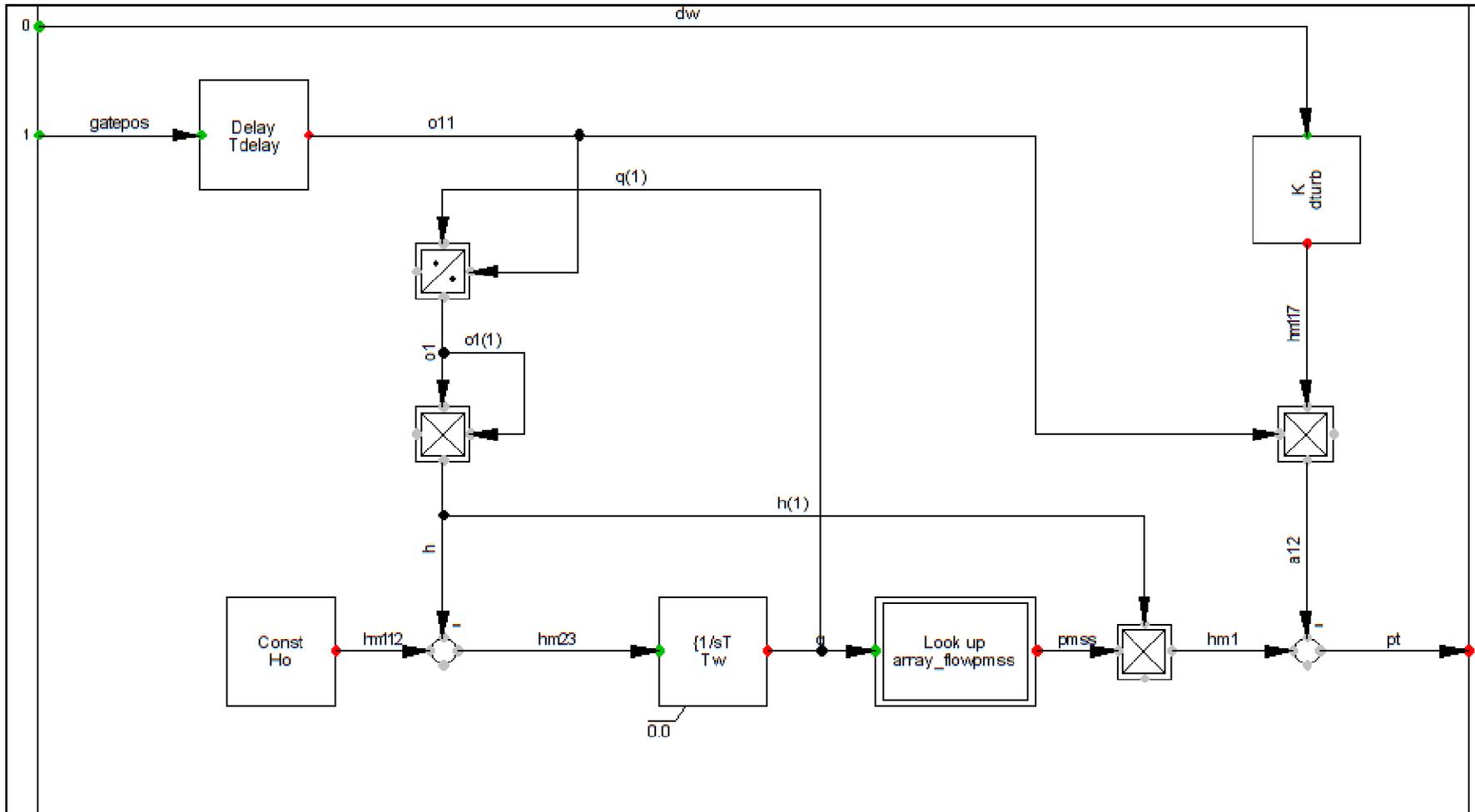
Plant/Frame Model: Common Penstock



Excitation System Model(Standard SEXS Model)



Turbine and Penstock Model – Single Penstock



Nonlinear Model of Multiple Penstocks and Turbines Supplied from Common Tunnel [Ref1]

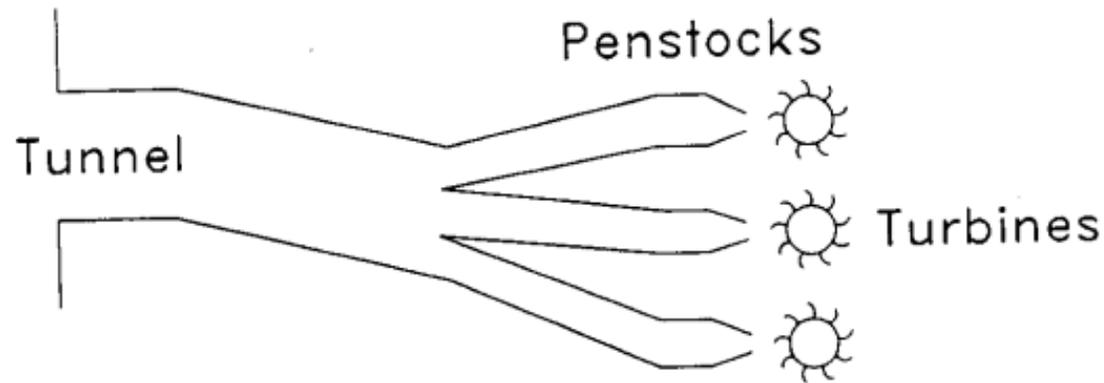
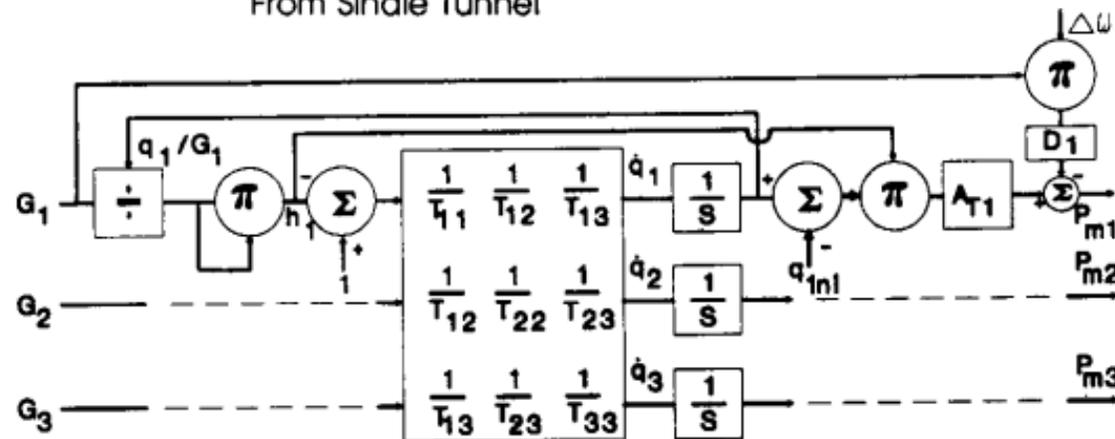
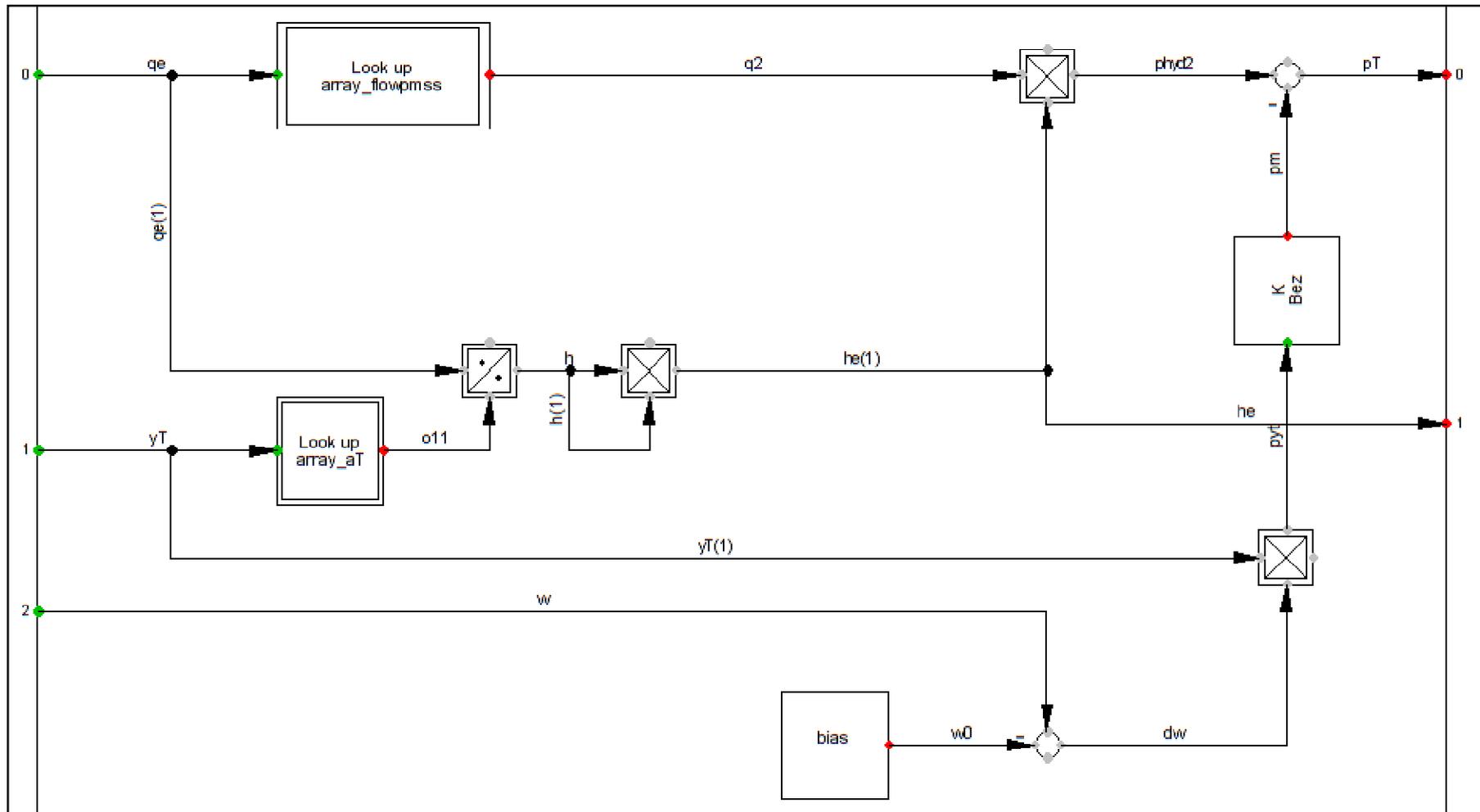


Figure 7. Penstock Arrangement Fanning Out From Manifold From Single Tunnel



Turbine Model – Common Penstock



Penstock Time Constant (Water Starting Time Constant)

- Constant diameter penstocks:

$$T_w = \frac{Q \times L}{g \times H \times A}$$

where Q is the maximum flow rate (m^3/s), H is the head (m), L is length of penstock (m), A is penstock area (m^2), and $g=9.8m/s^2$ is the gravity constant.

- Varying diameter penstocks:

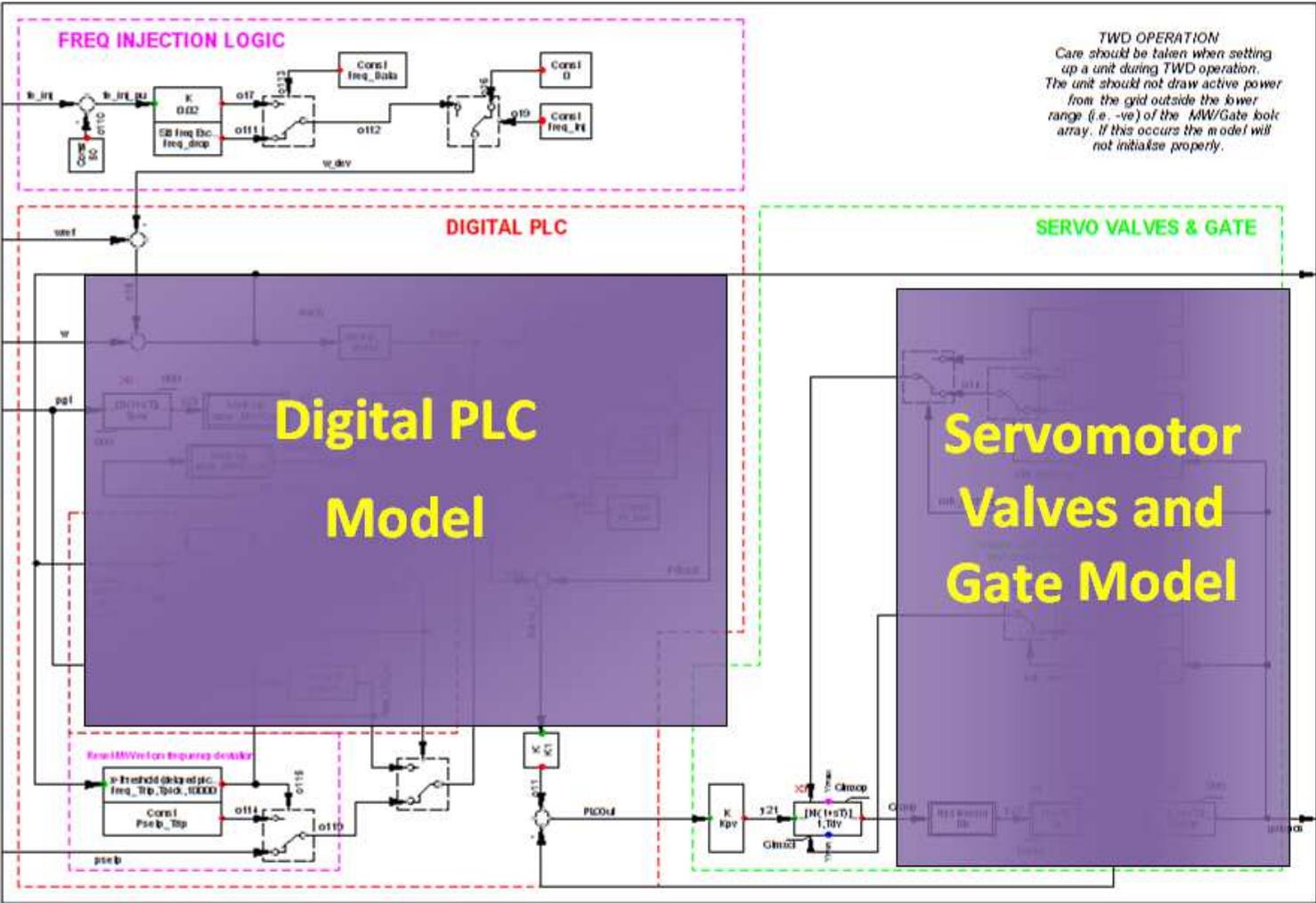
$$T_w = \frac{Q}{g \times H} \sum_{i=1}^n \frac{L_i}{A_i}$$

Station	Q (m^3/s)	H (m)	L (m)	A (m^2)	T_w (s)
1A	42	27	173.7	10.18	2.71
2A (Common Section)	37	223.5	650	3.1	3.57
2A-1/2A-2 (Individual Section)	37	223.5	50	3.1	0.27
2A-3 (Individual Section)	37	223.5	125	1.86	1.13
3	19	50.57	88.5	4.1	0.83
4	19	57.3	108	4.1	0.9



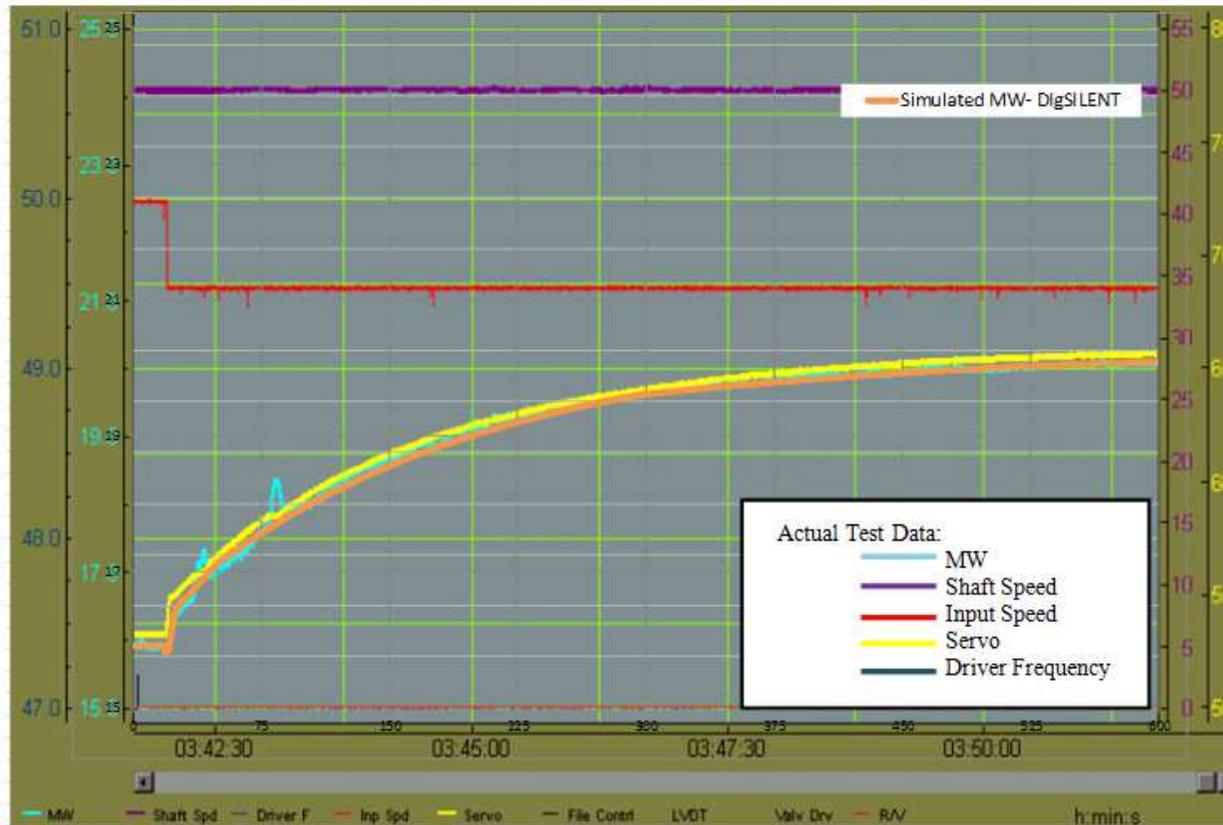
Governor Model

Trustpower_DIG-GOV1:



Governor/Turbine Tests

- 1.1. On-line Frequency Step Test (Unit G2A-1)

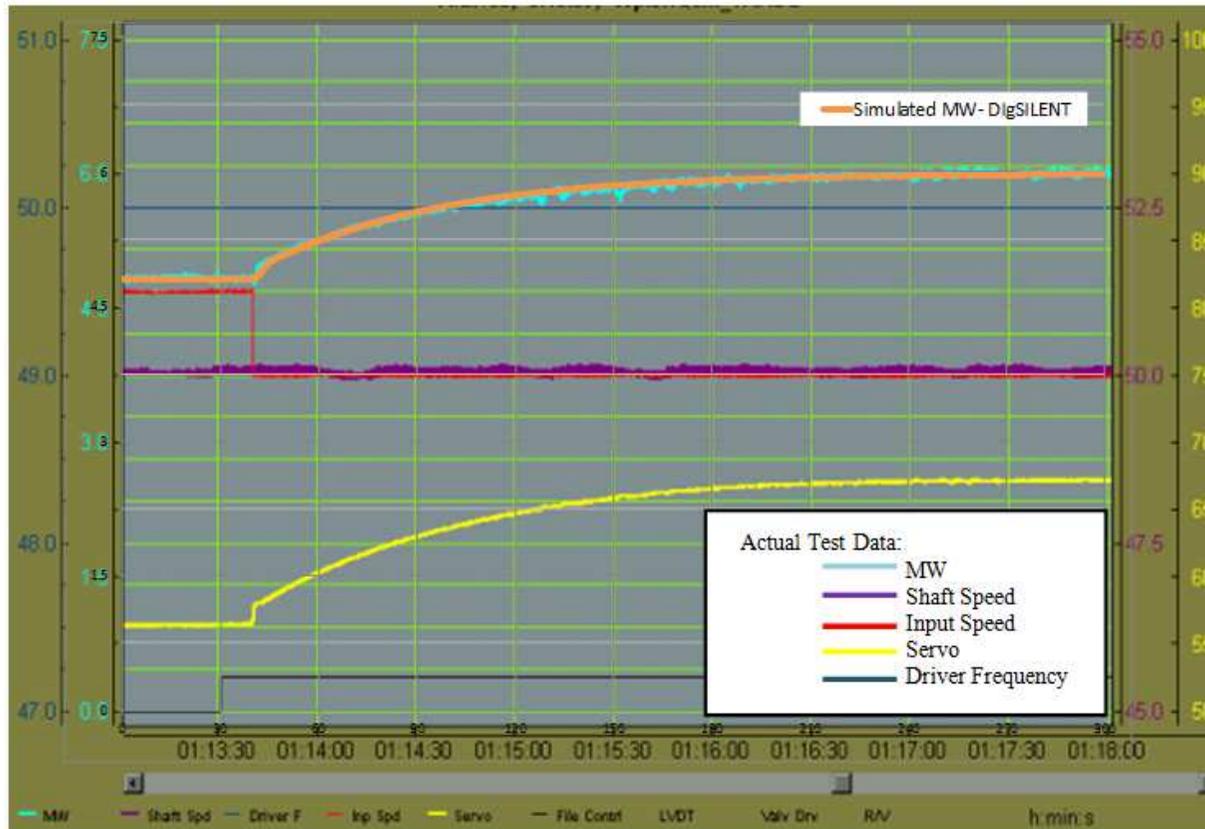


G2A-1: On-line under frequency injection: Simulated vs Test



Governor/Turbine Tests

- 1.2. On-line Frequency Step Test (Unit G3)

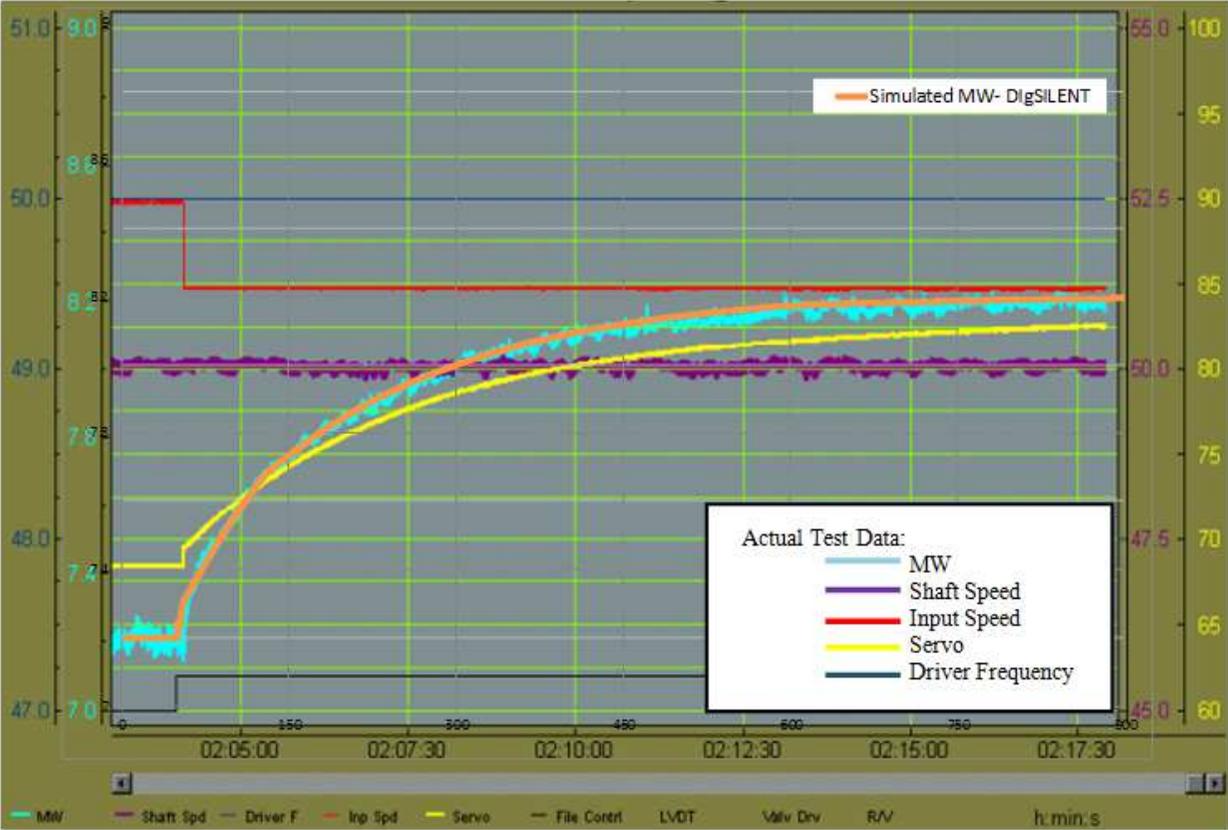


G3: On-line under frequency injection: Simulated vs Test



Governor/Turbine Tests

- 1.3. On-line Frequency Step Test (Unit G4)

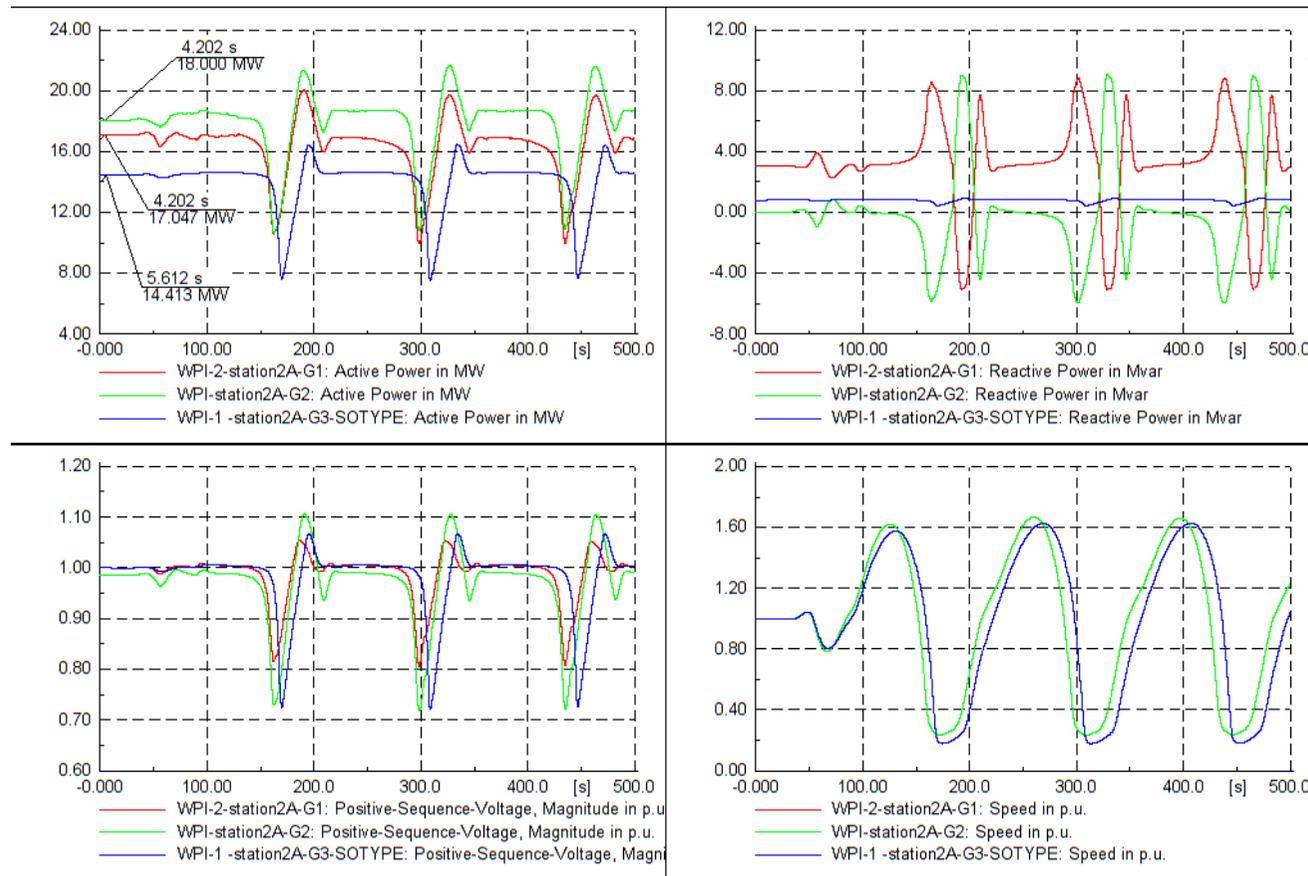


G4: On-line under frequency injection: Simulated vs Test



Governor/Turbine Tests

- 2.1. Governor Stability (Station 2A): As-left PID Parameters

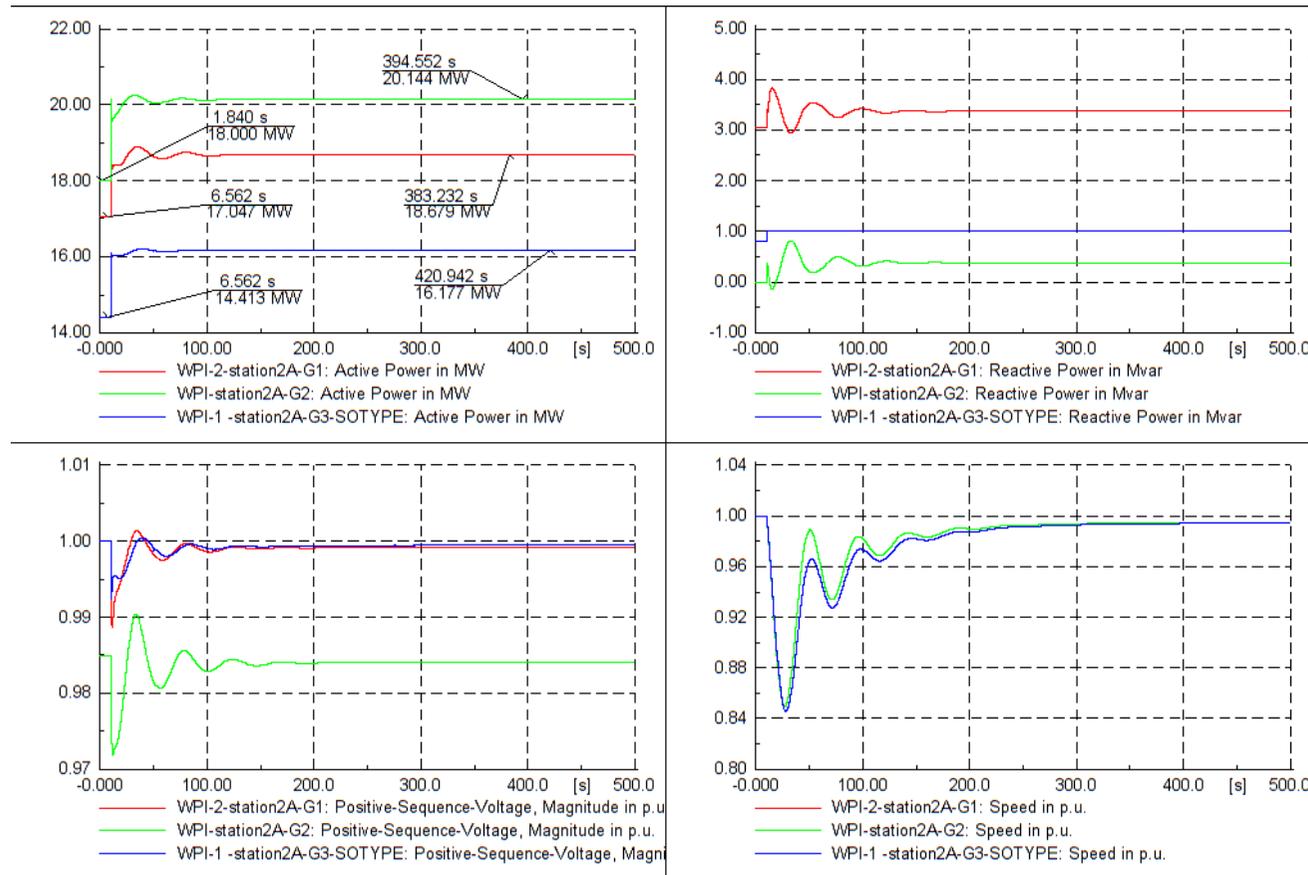


as-left PID parameters: $K_p=2$ and $K_i=0.14$



Governor/Turbine Tests

- 2.1. Governor Stability (Station 2A): Modified PID Parameters

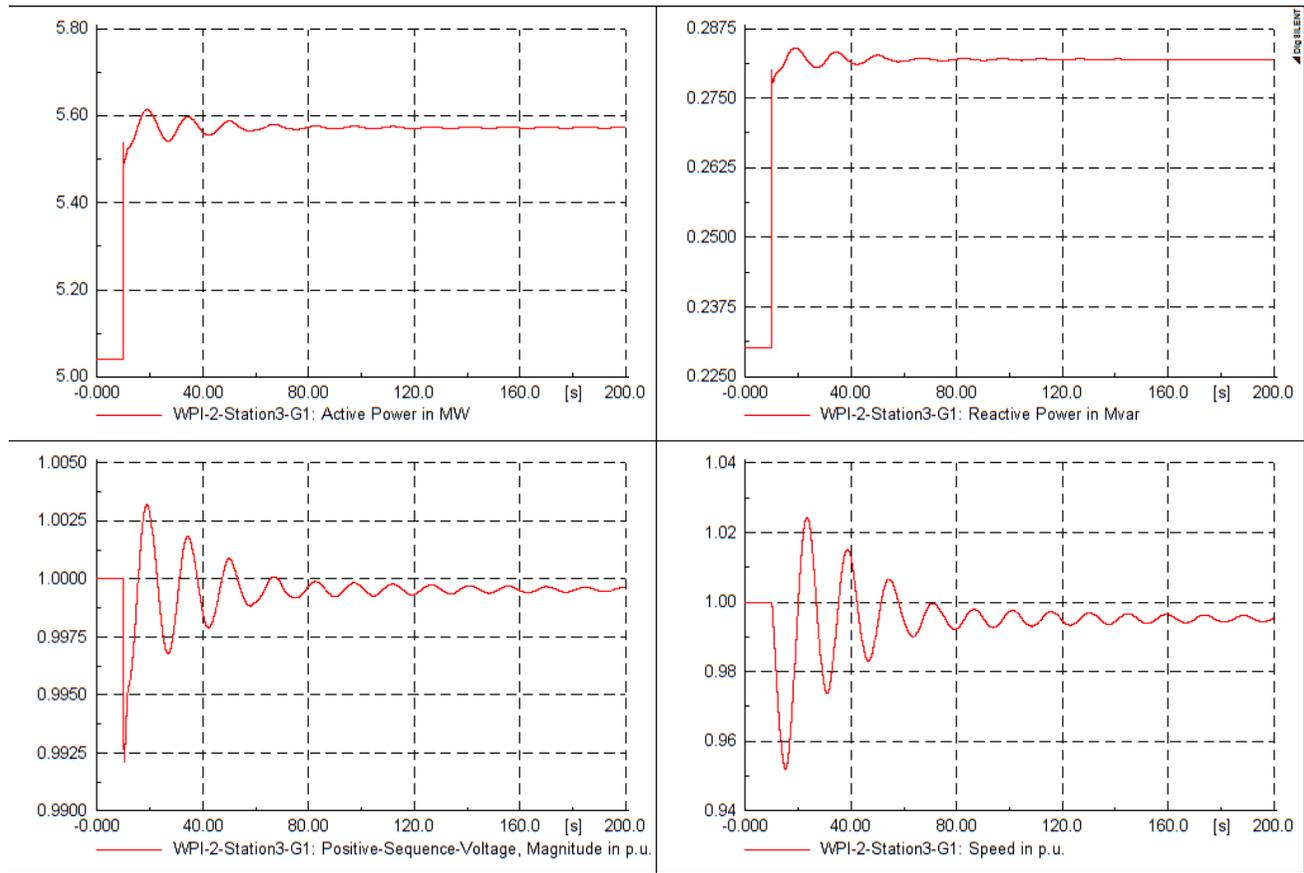


modified PID parameters: $K_p=0.5$ and $K_i=0.01$



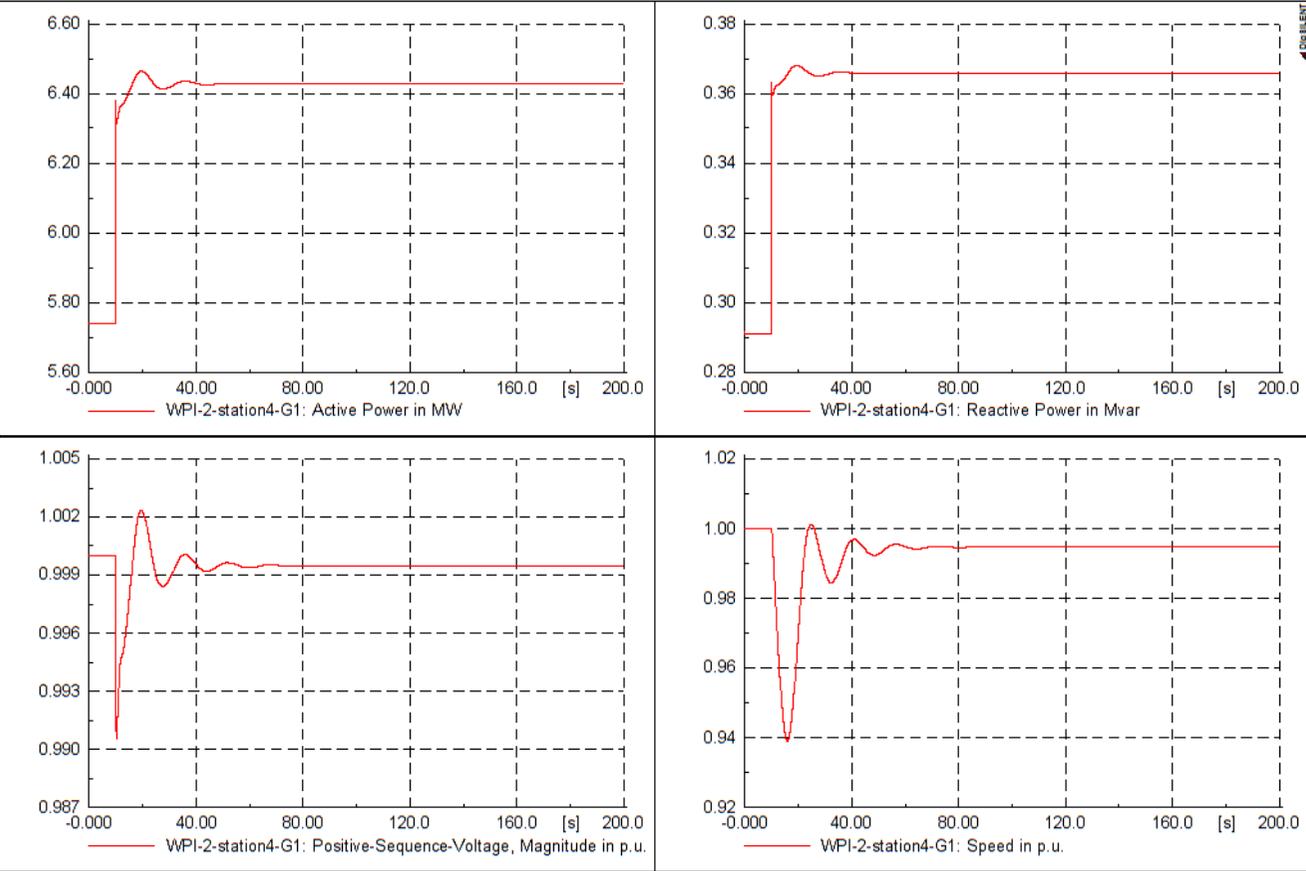
Governor/Turbine Tests

- 2.2. Governor Stability (Station 3): As-left PID Parameters



Governor/Turbine Tests

- 2.3. Governor Stability (Station 4): As-left PID Parameters



Conclusion

- The Governor/Turbine model is capable of predicting the plants' behaviour during frequency excursions (for the stations 2A, 3 and 4).
- The DIgSILENT model implemented (using the as-left parameters) for station 2A predicts sustained oscillatory behavior (not unstable) after a small step change in resistive load (all units operating at 80% load whilst isolated from the grid). It can be rectified by adjusting the PID parameters.
- The plant model implemented (using the as-left PID parameters) for stations 3 and 4 predicts stable and damped behaviour at entire range of active output power (whilst isolated from the grid)



References

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- 2) “**Electricity Industry Participation Code**”, Electricity Authority, New Zealand:
<http://www.ea.govt.nz/act-code-regs/code-regs/the-code/>
- 3) “**Waipori 3 Power Station, Unit No. 1 - Governor Replacement Commissioning**”, Contech Services Ltd report dated November 2008.
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Thank You

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