Modeling Notification

Gas Turbine Governor Modeling

Initial Distribution: August 2017

This Modeling Notification recommends reviewing application of the *GAST*, *GAST2A*, *GASTWD*, *GFT8WD*, and *WESGOV* turbine-governor models to gas turbine generators with modern digital controls. These models do not have the capabilities and flexibility of more recently developed models, and should not be used in the future. Default manufacturer data for the more flexible *GGOV1* model is provided as a starting point for verification of the updated model using *GGOV1*[1]. Considerations when transitioning to *GGOV1* are also provided.

Primary Interest Groups

Generator Owners, Generation Operators, Transmission Operators, Transmission Planners, Planning Coordinators, Reliability Coordinators, MOD-032 Designees

Background

The *GAST*, *GAST2A*, *GASTWD*, *GFT8WD*, and *WESGOV* models are simple representations of a turbine-governor control system, developed and introduced as early as the mid-1970s. These models are considered obsolete and should not be used for representing new generators and applicable existing generators. Most modern digital gas turbine governor control systems employ a proportional-integral (PI) controller that cannot be captured using these models. Some examples of the limitations of each of these models include:

- ***GAST*****:** simple droop control, constant load limit (rating of turbine), only three time constants (fuel valve response, turbine response, and load limit response), and neglects all aspects of the physics of heavy-duty gas turbines
- ***GAST2A*****:** assumes proportional speed governor control, does not allow for representation of intentional deadband, exhaust temperature control based on actual temperature limit instead of a proxy for MW output (as done in *GGOV1*)
- ***GASTWD*****:** similar to *GAST2A* but with a PID control structure. Also does not allow representation of intentional deadband and the exhaust temperature control is based on actual temperature limit rather than a MW output proxy
- ***GFT8WD*****[2]:** user-written model with no block diagrams or documentation in standard model libraries
- ***WESGOV*****:** a simple proportional-integral control that does not include any provisions for modeling the temperature limit of the turbine

[1] IEEE Power System Dynamic Performance Committee, "Dynamic Models for Turbine-Governors in Power System Studies," IEEE PES-TR1, Jan 2013. Available: http://sites.ieee.org/fw-pes/files/2013/01/PES_TR1.pdf.

[2] User-written model based on *GAST2A* and *GASTWD* models, developed by PTI for Pratt & Whitney to represent the PWPS FT8 turbine.

A high-level description of the *GGOV1*[3,4] model and default data supplied by the original equipment manufacturers (OEMs) for the *GGOV1*[5] model are provided for reference.

Modeling Notification

All recipients of this Modeling Notification using the *GAST*, *GAST2A*, *GASTWD*, *GFT8WD*, or *WESGOV* model to represent a modern turbine-governor system in stability programs are advised to consider reviewing the applicability of these models. This can be achieved by performing disturbance-based power plant model verification, performing or reviewing baseline testing results, and verifying the governor control logic compared with the model structure. The following recommendations are made:

- Generator Owners should review the control logic of their turbine-governor control system. Modern digital controllers generally use a PI control, which is not able to be fully represented using these models. If it is determined that this is the case, Generator Owners should proactively update their dynamic model to a more representative model in coordination with the OEM for that system.
- Generator Owners should transition to using the *GGOV1* model for generating units currently modeled using these models. This transition should occur upon (re)verification of the dynamic models for MOD-027-1 or any other opportunity to effectively make this transition.
- Generator Owners are encouraged to work closely with their Transmission Planner to ensure an effective and efficient transition to a representative *GGOV1* model.
- Future model submittals of the *GAST*, *GAST2A*, *GASTWD*, *GFT8WD*, or *WESGOV* models should be discouraged or disallowed by the MOD-032 Designees, Planning Coordinators, and Transmission Planners, unless dynamic model performance can be verified with verification test results. This will ensure that these obsolete models are phased out over time.
- Generator Owners and Transmission Planners with a dynamic disturbance recorder (e.g., phasor measurement units (PMUs)) monitoring the dynamic response of any resourced modeled with these models should perform disturbance-based power plant model verification to identify potential units with a mismatch between modeled and actual response.

The NERC List of Acceptable Models will be updated to reflect these recommendations.

[3] See above IEEE reference and CIGRE Technical Brochure 238, Modeling of Gas Turbines and Steam Turbines in Combined-Cycle Power Plants, December 2003. Available: [HERE.]

[4] Some regions may use the CIGRE gas-turbine model developed in the early 2000's. This model is very similar to, and was developed at the same time as, *GGOV1* and is equally acceptable. However, the model may not be available in all commercially available power system simulation tools used in North America. *GGOV1* is a more prevalent model. See footnote above for link to the CIGRE Technical Brochure.

[5] The intentional deadband in *GGOV1* may or may not match the actual implementation of modern digital governor controls. This issue may or may not have a substantive impact on system-wide planning studies.

Appendix A: *GGOV1* Model Description

The *GGOV1* model is a general purpose governor model used for a variety of prime movers controlled by proportional-integral-derivative (PID) governors including gas turbines. The model also includes control blocks to represent:

- Valve position and actuation
- Fuel system dynamics
- Load limiter for exhaust temperature controls
- Load controller for plant-level or outer loop controls
- Acceleration limiter
- Governor deadband

Figure 1 shows the block diagram of the *GGOV1* model.

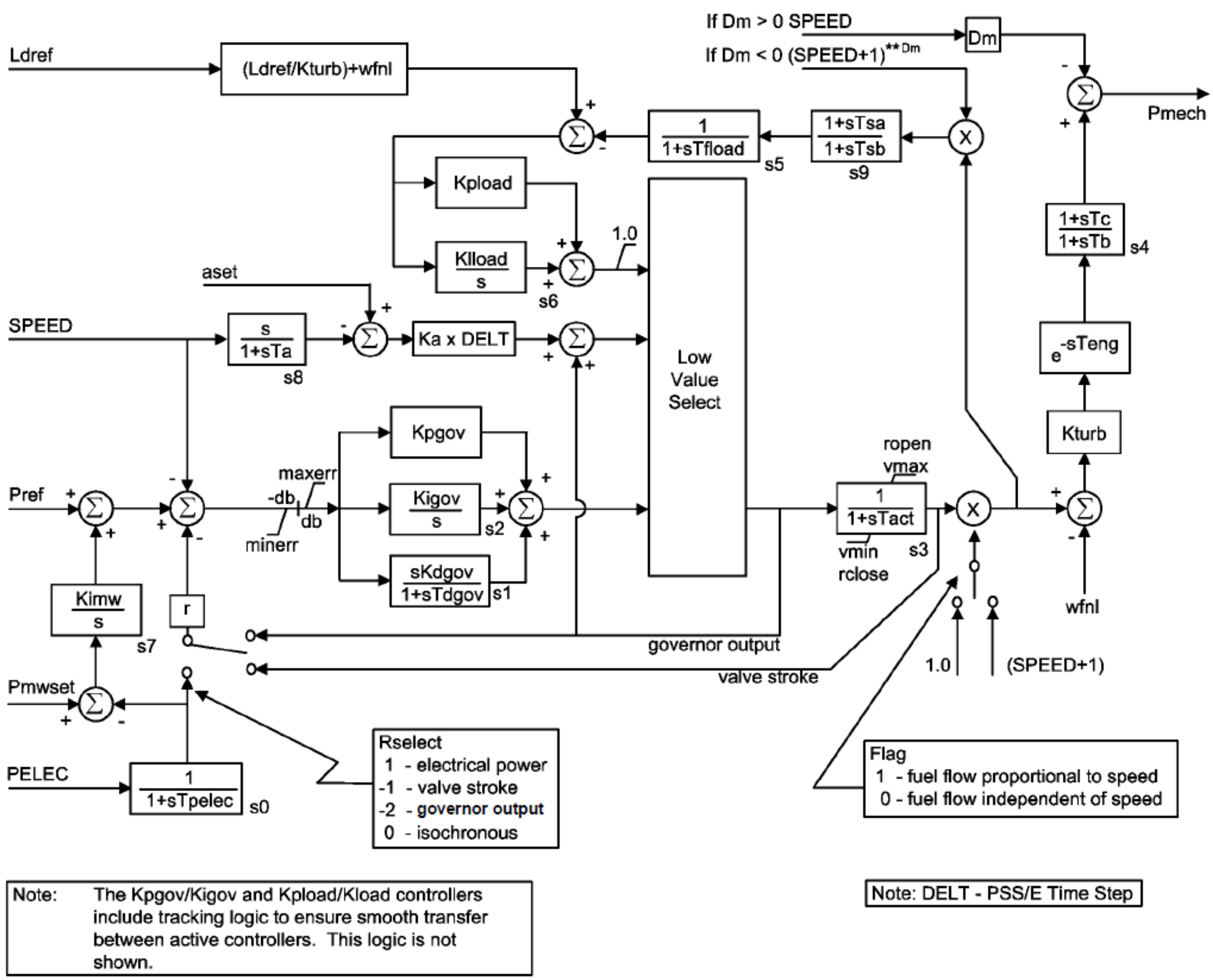

Figure 1: *GGOV1* Model (Courtesy of Siemens PTI PSS®E)

Table 1 provides default parameters for the *GGOV1* model. The listed parameters are intended to be a reference or starting point for creating a pro forma model. The model should then be verified through power plant testing or possibly disturbance-based verification methods. The OEM can be contacted with any detailed questions regarding manufacturer-specific dynamics models.

Table 1: Steady-State Metrics

GE Frame[1]	GE Aero-Derivative[2]	Siemens[3]	PWPS[4]	MHPSA[5,6]	Description
					Turbine Rating (MW)
0.04	0.05	0.04	0.04	0.04	R, Permanent droop (pu)
1	1	1	1	1	Rselect, (1: Pelec, 0: none, -1: fuel valve stroke, -2: governor output)
1	0.5	0.1	0.1	1	Tpelec, Electrical power transducer time constant (sec)
0.05	0.05	0.05	0.1	0.05	Maxerr, Maximum value for speed error signal (pu)
-0.05	-0.05	-0.05	-0.1	-0.05	Minerr, Minimum value for speed error signal (pu)
10	1.9-3	27.6	1.2	10	Kpgov, Gov. proportional gain
2	0.8-1.1	7.7	3.6	0	Kigov, Gov. integral gain
0	0	0	0	0	Kdgov, Gov. derivative gain
1	1	1	1	999	Tdgov, Gov. derivative controller time constant (sec)
1	1	1	1	1	Vmax, Maximum valve position limit
0.15	0.09-0.24	0.1	0.1	0.1	Vmin, Minimum valve position limit
0.5	0.3-0.4	0.3	0.25	0.3	Tact, Actuator time constant (sec)
1.5	2-2.7	1.24	2.5	1.24	Kturb, Turbine gain
0.2	0.095-0.26	0.196	0.2	0.196	Wfnl, No load fuel flow (pu)
0.1	0.1	0.59	0.5	0.59	Tb, Turbine lag time constant (sec)
0	0	0	0	0	Tc, Turbine lead time constant (sec)
0	0	0	0	0	Teng, Transport lag time const for diesel engine (sec)
3	3	3	0.75	3	Tfload, Load Limiter time constant (sec)
2	4	2	2.5	2	Kpload, Load limiter proportional gain for PI controller
0.67	2	0.67	7.5	0.67	Kiload, Load limiter integral gain for PI controller
1	1.005	10	1	10	Ldref, Load limiter reference value (pu)
0	0	0	-0.13	0	Dm, Mechanical damping coefficient (pu)
0.1	99	0.1	3.3	0.1	Ropen, Maximum valve opening rate (pu/sec)
-0.1	-99	-0.1	-3.3	-0.1	Rclose, Maximum valve closing rate (pu/sec)
0	0	0	0.50	0	Kimw, Power controller (reset) gain
N/A	N/A	N/A	N/A	N/A	Pmwset[7], Power controller setpoint (MW)
0.01	10	9999	0.01	0	Aset, Acceleration limiter setpoint (pu/sec)
10	10	0	10	0	Ka, Acceleration limiter gain
0.1	0.1	0.1	0.01	0	Ta, Acceleration limiter time constant (sec)
0	0	0.005	0	0	db, Deadband (pu)
4	1	1	10	1	Tsa, Temperature detection lead time constant (sec)
5	1	1	1	1	Tsb, Temperature detection lag time constant (sec)
99	99	99	99	99	Maximum rate of load limit increase (pu)
-99	-99	-99	-99	-99	Maximum rate of load limit decrease (pu)

[1] IEEE Power & Energy Society, "Dynamic Models for Turbine-Governors in Power System Studies," Technical Report PES-TR1, Appendix C, pp. C-1, Jan 2013.
[2] These settings are based on the type of GE aero-derivative machine being modeled. Check with GE for correct default values.
[3] Standard 5000F(5ee) Engine model default parameters. Other large frame Siemens engines (8000H and 2000E) do not utilize the *GGOV1* model, as the *GGOV1* is not representative of the expected output of the governor used on those frames.
[4] P.W. Power Systems. Data provided by P&W for the P&W FT4000 at high power output on Np control.
[5] Mitsubishi Hitachi Power Systems Americas
[7] NOTE: This data was provided by review of relatively new, existing MHPSA units on-line. This data was not provided by MHPSA directly. In any case, one should contact the OEM, use verification reports, and equipment documentation to get exact parameters.
[7] This is initialized off of the powerflow solution and not a user-defined value. The user can change it during the simulation after initialization.

It is important to note that power plants may be retrofitted with third party controllers and the default parameters would not apply to these control systems. While testing and verification is necessary in all cases to make a model change, these cases are particularly important to call out and ensure the types of equipment and control systems are considered in the selection of an appropriate model and model parameters. Furthermore, the parameter values provided above are typical values or ranges. Some parameters (e.g., controller gains) are tunable and may change from case to case, and should be refined to the extent possible to represent the actual installation.

Comments related to the pro forma turbine-governor model parameter values provided in Table 1:

- A value of 4 or 5 percent droop (R = 0.04 or R = 0.05, on turbine MW rating) is a common governor droop setting and recommended by NERC for most bulk power system turbine-governors.
- Kpgov, Kigov, Kdgov, Tdgov are the governor proportional-integral-derivative (PID) gains and time constants. These may need to be converted from the PID settings in the digital control logic using information from the original equipment manufacturer (OEM).
- The ratio between proportional gain, Kp_{gov}, and integral gain, Ki_{gov}, is generally 5 or 10 depending on application.
- Most modern digital gas turbine governors employ a proportional-integral gain (PI) controller. In this case, derivative gain, Kd_{gov}, is set to 0 and derivative time constant, Td_{gov}, is set to 1.
- Maximum and minimum valve position limits, V_{max} and V_{min}, are generally set to 1 and 0.05 since, by definition, the valve can be fully opened (1) and generally there is a limit on the minimum valve opening when the turbine is running.
- Turbine gain, K_{turb}, is calculated as 1/(fuel flow at full load – wfnl) on turbine MW rating.
- No load fuel flow, W_{fnl}, should be verified in the field or provided by the OEM.
- Turbine rating, T_{rate}, is based on the nameplate rating of the turbine[6] and must be collected from the manufacturer data.
- It is common for turbine-governor manufacturers to include a small yet noticeable intentional deadband in the controls to avoid constant valve movement. These are typically on the order of

[6] The turbine rating is not to be confused with machine MVA rating (M_{BASE}). Turbine rating is usually expressed in MW, and represents the maximum real power generating capability of the turbine under ISO conditions (i.e., ambient temperature of 59°F, etc.). *GGOV1* uses Turbine Rating in all major commercial software platforms in North America, while *GAST* uses Machine MVA Rating as the base in some of the commercial software platforms. Be aware of any potential change in base MVA value.

0.00025-0.0006. The deadband should be modeled correctly in the turbine-governor model to accurately capture governor response from the unit.

- The feedback signal for governor droop, R_{select}, is generally set to 1, representing machine electrical output power used as the governor input.
- The flag switch, Flag, for fuel source is generally[7] set to 0, representing fuel flow independent of machine speed.
- Acceleration limiter set point, gain, and time constant (A_{set}, K_a, T_a) are generally set to 99, 10, and 0.01, respectively. Many manufacturers (but not all) disable the acceleration control loop once the turbine is on-line and producing power.
- A negative mechanical damping coefficient, D_m, refers to engine power assumed to be unaffected by shaft speed, but the maximum permissible fuel flow falls with falling shaft speed, common of single shaft industrial gas turbines. A positive value refers to a falling slope of engine speed versus power characteristic typical of reciprocating engines and some aero-derivative turbines. Typically, however, for power system studies Dm should be set to zero.

OEM Contacts

Table 2 provides OEM contact information for further questions.

Table 2: Steady-State Metrics

OEM	Contact Name	Email
General Electric	Dan Leonard	daniel1.leonard@ge.com
Siemens-Westinghouse	Dan Kozachuck	dan.kozachuk@siemens.com
P.W. Power Systems	Todd Landry	todd.landry@pwps.com
MHPSA	Daniel O'Callaghan	daniel.ocallaghan@mpshq.com

[7] Some heavy duty turbines have shaft driven fuel pumps where this flag should be set to 1.

Appendix B: *GAST* Model Description

The *GAST* gas turbine governor model represents the basic characteristics of a gas turbine driving an electrical generator connected to the bulk power system. The model parameters represent:

- T1: governor time constant
- T2: combustion chamber time constant
- T3: load limit time constant (exhaust gas measurement time)
- K_T: load limit feedback gain
- R: droop; reciprocal of the proportional gain (e.g., R = 0.05 pu is K_p = 20)
- D_{turb}: speed damping coefficient of gas turbine rotor
- V_{MAX}: operational control high limit on fuel valve opening
- V_{MIN}: low output control limit on fuel valve opening

Ambient temperature load limit, AT, is defined as a model input, and typical values are 1.0 for 80°F (rated) and 0.9 for 105°F.

Load Reference is defined as the shaft mechanical power P_{MECH} when the model initializes. The *GAST* model uses rotor speed as the governor input signal.

NOTE: This model is a simplistic representation of the basic features of a gas turbine control system and should not be used to model modern digital turbine-governor control systems.

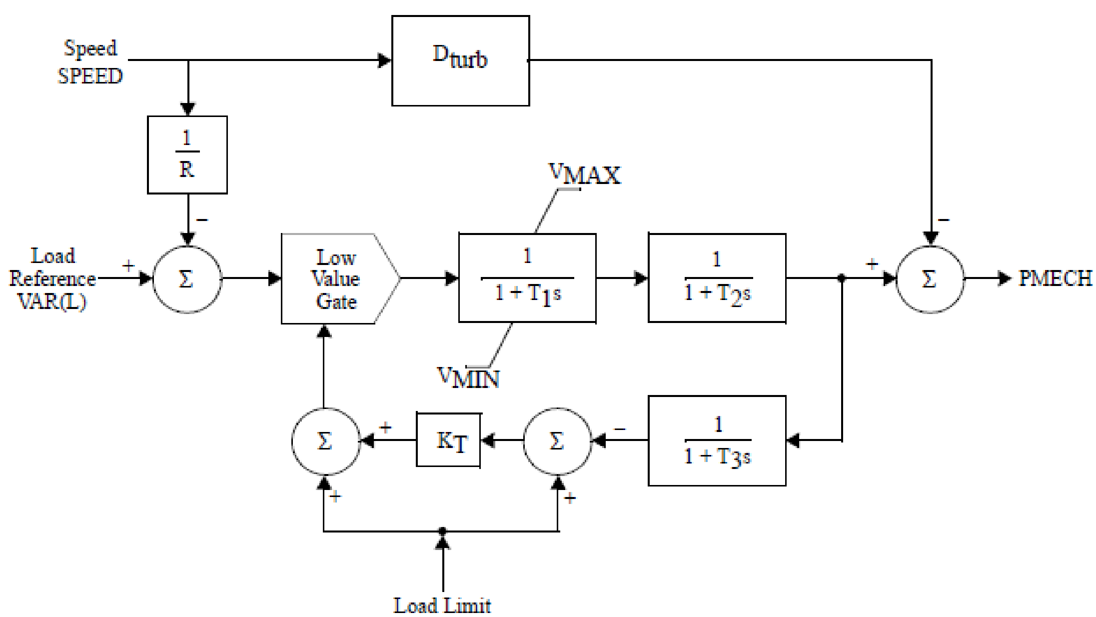

Figure 1: *GAST* Model (Courtesy of Siemens PTI PSS®E)