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Title: Bond graph add-on block library BG V.2.1

MATLAB Release: R2007a

Required products: Simulink

Keywords: bondgraph, bond graph, power flow, energy structure of systems, energy efficiency, power variables, flow, effort, half arrow, dissipate energy, store energy, gyrator, transformer, node, causality, field, momentum, displacement

Picture (600 pixel, none transparency)**:** BG_AnBei.jpg; BG_AnBei.doc

Summary: (100 characters) Block library enables the graphical programming of Bond Graphs using standard Simulink and editor.

Description: (5000 characters)

Abstract:
A customizable add-on library with a small number of blocks for the graphical programming of Bondgraphs is provided.

Why Bondgraphs?
Energy domain independently Bondgraphs are excellent power flow diagrams for process models [see A. Bouscayrol et al 'Different energetic descriptions of electromechanical systems', Proceedings of the 2005 European Conference on Power Electronics and Applications (EPE), CD: 665]. Connections between two elements consist of a line including a half arrow which is marking the preferred power flow direction. Assigned to a connection are two power variables: effort and flow. The product of these variables must be a power value. A detailed introduction to Bondgraphs is given in [http://www.bondgraph.info/about.html] for instance.

Example:
'ElaWe_GM_ZuReg.mdl' demonstrates the well known DC motor (including elastic shaft and state control) and it's Bondgraph as an example. Voltage and torque correspond to effort as current and angular velocity correspond to flow. Gyrator GY transforms power between two energy domains lossless and without delay, R elements implement losses and I elements symbolise energy storages. Short lines at one side and perpendicularly of a half arrow connection determine the computation causality and a known flow variable. Whereby an integral causality is the goal, i.e. E (effort) input for I element. Nodes of 1 or 0 type model power balances. C storages as converse of an I storage and transformers TF as complements to gyrators are not used for this example. For more annotations please see: G.-H. Geitner 'Power Flow Diagrams Using a Bond Graph Library under Simulink', IEEE-IECON 2006, Paris, CD (SS19: Graphical description for modelling and control of power systems), 06.11.-10.11.06 or International Workshop MCES [Modelling and control of electrical systems] 2006, Lille (France): http://l2ep.univ-lille1.fr/commande/iw/presentations/lec-geitner.htm.

Realization using Simulink:
Replace each half arrow connection by one visible connection drawn by the standard editor, presenting optionally a flow or an effort connection and

implementation of the back connection for the complementary power variable effort or flow using software background. In addition the blocks should be defined switchable e.g. regarding causality or block function to reduce the number of library blocks. Library version 2.1 consists of 9 blocks only which realize the whole necessary functionality. These blocks may be used by means of drag & drop technique as usual in Simulink.

Features:
Typical examples for a summarisation of the functionality are the energy storage block – choice of I or C type resp. the node block – choice of 0 or 1 type. Environment connection to standard Simulink blocks ensure S/D and AB blocks which have a monopoly for this task, i.e. a controller may only drive a Bondgraph by means of a S/D block. A measurement of variables of a Bondgraph may only be done by use of an AB block. All blocks are able to operate with scalar or vectorial bond connections optionally. The user may set constant parameters directly via block mask or work with variable parameters by defining an additional parameter input if allowable for the considered element like TF or GY. The applicable block masks offer different additional adjustments like number of inputs and outputs as well as operation mode for node blocks or initial values resp. additional momentum or displacement outputs regarding energy storages I and C. Each block provides a protection of its functionality, i.e. a first mask access only allows a change of the parameter value. Operation mode modifications must be unlocked in a second step. Programming a second file filename_P.m causes the allocation of determined or calculated numerical values to symbolic defined parameters of each element.

Nodes and measurements:
Since one power variable type of a node blocks power variable pairs has been defined to be constant there are two different icons per node type necessary. Icon appearance forms and underlying equations are documented. Any effort and flow variable of a Bondgraph may be measured by means of an AB block which realises the activated bond functionality whereas momentum and displacement variables are immediately disposal at storage elements. All kinds of measurement tasks may be solved by using given example solutions.

Summary:
The Simulink add-on BG V.2.1 offers a tool for the graphical programming of power flow diagrams in terms of Bondgraphs. Nine blocks ensure all essential modes via mask input. That way e.g. causality changes, nonlinearities, initial values, vectorial operation, power outputs or protection of settings are ensured. Examples describe the different usage as for process modelling, control loops or energy efficiency (VDI/VDE 3547, *Assessment of quality of motion systems and controlled sequences of motion*, Düsseldorf 2001) computation. Tool, examples and short documentation are included.