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Performance Analysis of RLC Series Circuit and DC Machine using Bond Graph Theory

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***Abstract*— This paper presents the Bond Graph formalism for modeling of electrical systems. Eelectrical models like series RLC circuit and DC machine are modeled by this approach for the analysis of their physical behavior. System equations are generated by using a step-by-step procedure from a bond graph diagram. Theoretical valuation is validated through the numerical simulation studies. MATLAB/SIMULINK software package is employed for simulation and corresponding results have been carried out.**

***Index Terms*—Bond graph, effort and flow, MATLAB/SIMULINK**

I. INTRODUCTION

Bond graphs are a domain-independent graphical description of dynamic behavior of physical systems. In 1959, Prof. H.M. Paynter invented the idea of portraying systems in terms of power bonds, connecting the elements of the physical system to the junction structures. This power exchange portray of a system is called Bond Graph which can be both power and information oriented. The idea was further developed by Karnopp and Rosenberg such that it could be used in practice. [1]

By this approach, a physical system can be represented by symbols and lines, identifying the power flow paths. The lumped parameter elements of resistance, capacitance and inductance are interconnected in an energy conserving way by bonds and junctions resulting in a network structure. The flow of energy between two elements (and thus a bond) is always characterized by two generalized conjugated variable e (effort) and f (flow), of which the product is power P. [2-4]

$$P = e\,f$$

In this technique, power flow is represented by a half bond. Every bond is associated with two variables, effort and flow and the causality indication.

II. BOND GRAPH STANDARD ELEMENTS

A. Basic 1-Port Elements

A 1-port element is addressed through a single power port, and at the port a single pair of effort and flow variables exists. Ports are classified as passive ports and active ports. The passive ports are idealized elements because they contain no power sources. The inductor, capacitor, and resistor are classified as passive elements. [5]

R-Element:

The R-element is expressed as generalized friction and contains effort and flow variables. It controls dissipation of power.

$$f(t) = \frac{1}{R}\, e(t) \qquad e(t) = R\, f(t)$$

Fig.1 R-bond

L-Element:

The inertia L-element expresses all effects containing effort and flow variables. It provides storage for power that includes inductance and inertia.

$$f(t) = \frac{1}{L}\int e(t)\,dt \qquad e(t) = L\frac{df(t)}{dt}$$

Fig.2 L-bond

C-Element:

The capacitance C-element expresses all effects containing effort and flow variables. It provides storage for power including condensers, springs and accumulators.

$$f(t) = C\frac{de(t)}{dt} \qquad e(t) = \frac{1}{C}\int f(t)\,dt$$

Fig.3 C-bond

Effort & Flow Sources:

The active ports are those, which give reaction to the source.

Fig.4 SE & SF-bonds

B. Basic 2-Port Elements:

There are only two kinds of two port elements, namely Transformer and Gyrator. The bond graph symbols for these elements are TF and GY, respectively. As the name suggests, two bonds are attached to these elements. [5]

TF-Element:

The transformer element can work in two ways; either it transforms a flow into another flow or it transforms an effort into another effort. 'm' is the transformation ratio.

$$e_1 = m e_2$$

$$f_2 = m f_1$$

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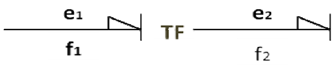


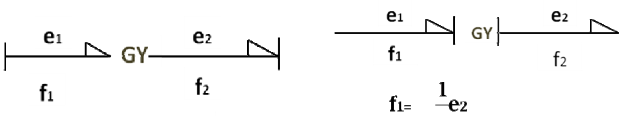
$$e_2 = \frac{1}{m} e_1$$

$$f_1 = \frac{1}{m} f_2$$

Fig.5 TF-bond

GY-Element:

The gyrator can work in two ways; either it transforms a flow into an effort or it transforms an effort into a flow. ‘r’ is the gyrator ratio.



$$e_1 = r f_2$$

$$e_2 = r f_1$$

$$f_1 = \frac{1}{r} e_2$$

$$f_2 = \frac{1}{r} e_1$$

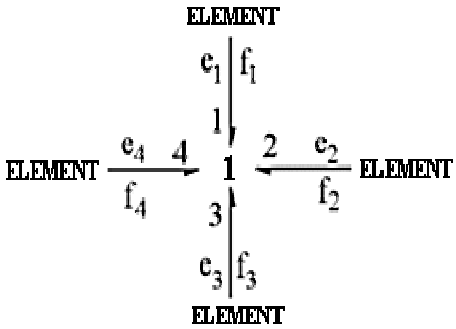
Fig.6 GY-bond

C. Multi-Port Elements:

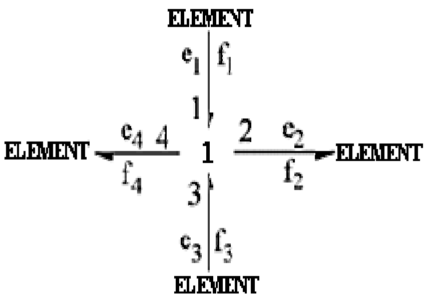
These include 0-junction and 1-junction. [4]

1-Junction:

The flows on the bonds attached to a 1-junction are equal and the algebraic sum of the efforts is zero. For series connections 1-junctions are used.



$$e_1 f_1 + e_2 f_2 + e_3 f_3 + e_4 f_4 = 0$$

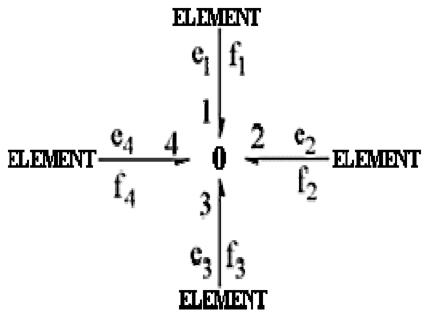


$$e_1 f_1 - e_2 f_2 + e_3 f_3 - e_4 f_4 = 0$$

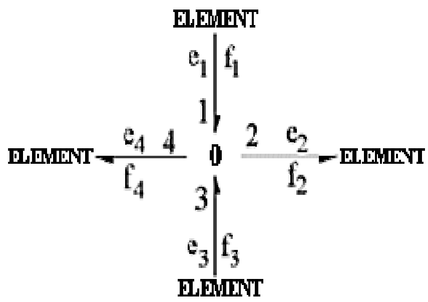
Fig.7 1-Junction

0-Junction:

The efforts on the bonds attached to a 0-junction are equal and the algebraic sum of the flows is zero. For parallel connections 0-junctions are used.



$$e_1 f_1 + e_2 f_2 + e_3 f_3 + e_4 f_4 = 0$$



$$e_1 f_1 - e_2 f_2 + e_3 f_3 - e_4 f_4 = 0$$

Fig.8 0-Junction

III. RLC SERIES CIRCUIT AND DC MACHINE

The R-L-C series circuit with a DC-voltage source is shown in Fig 9. Its bond graph model is shown in Fig.10. Several software packages have been developed for simulating the dynamic system behavior which allows processing of results in both time and frequency domains.

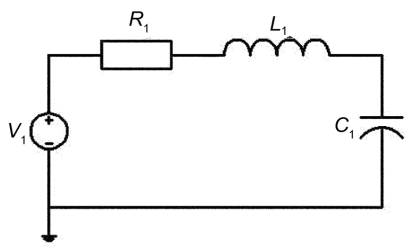
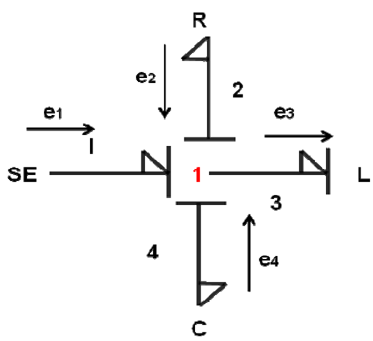


Fig.9 RLC Circuit



$$e_3 = e_1 - e_2 - e_4$$

$$f_1 = f_2 = f_3 = f_4$$

Fig 10. RLC Bond Graph

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Modeling of DC Motor:

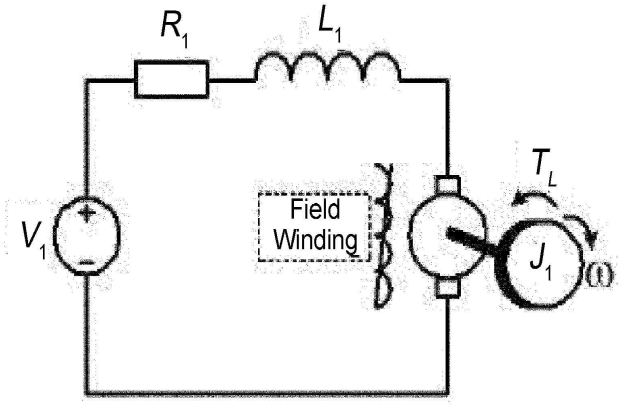

Fig 11. DC Machine

A. Classical Approach:

From the applied voltage and torque, the armature current and motor speed are given as follows

$$v_{App} = Ri + L\frac{di}{dt} + E \qquad T = J\frac{dw}{dt} + b\omega$$

$$= Ri + L\frac{di}{dt} + K_{\phi}\omega \qquad K_{\phi}i = J\frac{dw}{dt} + b\omega$$

$$i = \frac{1}{L}(\int (V_{appl} - Ri - K_{\phi}\omega)$$

$$\omega = \frac{1}{J}(\int K_{\varphi}i - b\omega)$$

B. Bond Graph Approach:

Fig.11 shows separately excited DC motor, which is taken as an example of multi-domain system. The load is rotational which can be considered as a disc. Its bond graph model is shown in Fig.12.

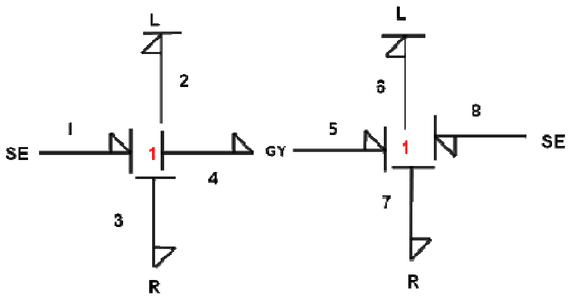

Fig 12. DC Machine Bond Graph

IV. RESULTS AND DISCUSSIKONS

For RLC Series Circuit, the value of R is 2 ohm, L is 1 mH and C is 100 *m*F. The DC voltage source is of value 10 V. The plots for transient response of capacitor voltage and inductor current are shown in Fig.13-14.

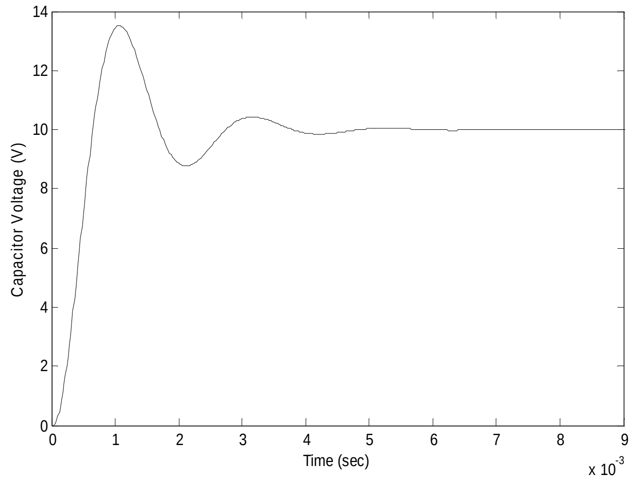

Fig.13. Capacitor Voltage

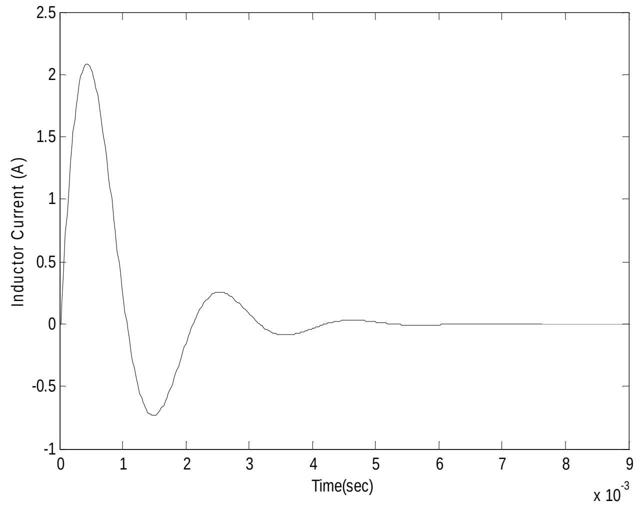

Fig.14. Inductor Current

The ratings of the DC motor are Rated voltage = 460 V, Rated current = 690 A, Rated power = 300 kW, Base speed = 500 rpm = 52.4 rad/s, Full load torque = 5730 Nm, Moment of inertia = 84 kg m2 = 824 Nm^2, Back emf constant = 8.5 Vs/rad, Armature resistance = 0.0234 and Armature inductance= 0.7026 mH.

The plots for armature current and motor speed of DC machine by classical approach are shown in Fig. 15-16.

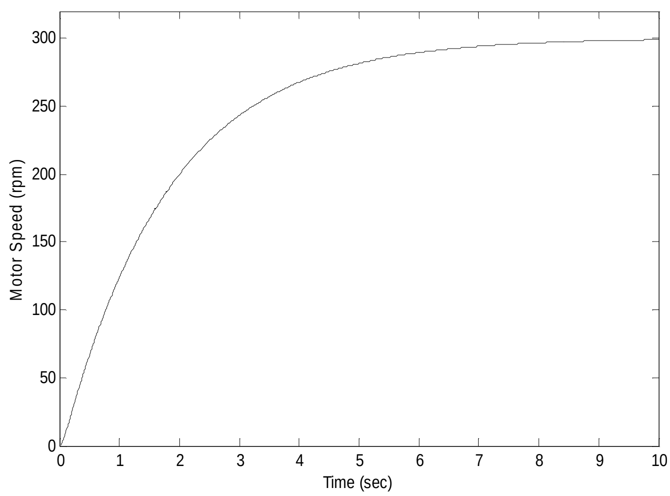

Fig.15. Motor Speed of DC Motor with classical Approach

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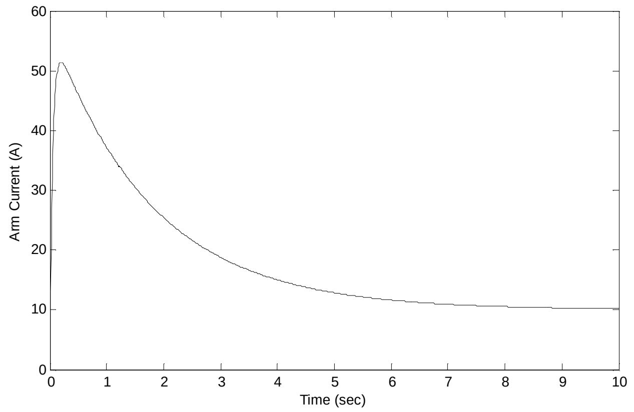

Fig.16. Armature Current with classical Approach

The plots for armature current and motor speed of DC machine by Bond Graph approach are shown in Fig. 17-18.

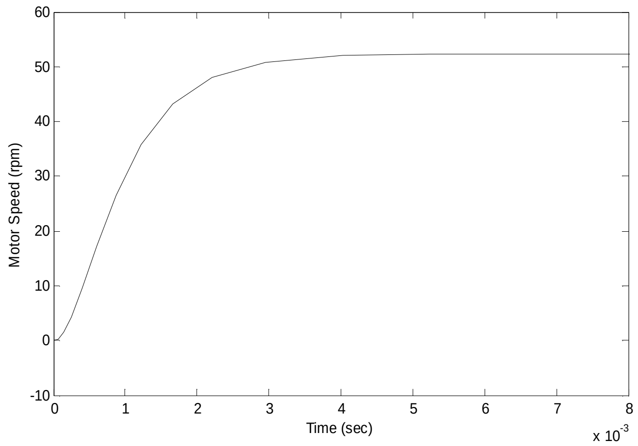

Fig.17. Motor Speed of DC Motor with Bond Graph Approach

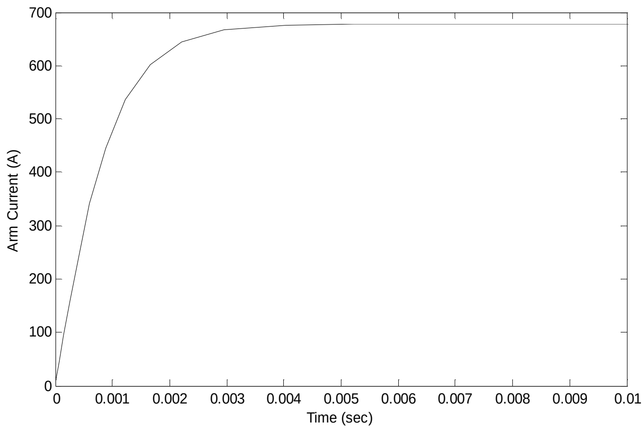

Fig.18. Armature Current with Bond Graph Approach

V. CONCLUSION

The number of computations is reduced by this approach once the bond graph is developed for any electrical equivalent circuit. MATLAB/SIMULINK is used for the present work where the bond graph models are implemented in the form of causality arguments and state-space equations. From the results, it is observed that the motor speed and armature current of DC machine obtained are almost identical for both classical and bond graph approach with less number of computations in bond graph approach.

REFERENCES

1. Amod C. Umarikar, Tusharkant Mishra And L. Umanand , “Bond Graph Simulation And Symbolic Extraction Toolbox In Matlab/Simulink”, J. Indian Inst. Sci., Jan.–Feb. 2006, pp 45–68.
2. José Antonio Calvo, Carolina Álvarez- Caldas and José Luis San Román, “Analysis of Dynamic Systems Using Bond Graph Method Through SIMULINK” Sapin.
3. Samantaray, www.bondgraphs.com, 2001, pg.1-25.
4. Jan F. Broenink, “Introduction to Physical Systems Modelling with Bond Graphs” University of Twente, Dept EE, Control Laboratory
5. Amalendu Mukherjee, Arun Kumar Samantaray, Ranjith karmakar,” Bond Graph In Modeling, Simulation And Fault Identification”I.K.Publishers..

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