World Academy of Science, Engineering and Technology
International Journal of Mathematical and Computational Sciences
Vol:14, No:12, 2020

Thermodynamic Analyses of Information Dissipation along the Passive Dendritic Trees and Active Action Potential

Authors : Bahar Hazal Yalçınkaya, Bayram Yılmaz, Mustafa Özilgen

Abstract : Brain information transmission in the neuronal network occurs in the form of electrical signals. Neural work transmits information between the neurons or neurons and target cells by moving charged particles in a voltage field; a fraction of the energy utilized in this process is dissipated via entropy generation. Exergy loss and entropy generation models demonstrate the inefficiencies of the communication along the dendritic trees. In this study, neurons of 4 different animals were analyzed with one dimensional cable model with N=6 identical dendritic trees and M=3 order of symmetrical branching. Each branch symmetrically bifurcates in accordance with the 3/2 power law in an infinitely long cylinder with the usual core conductor assumptions, where membrane potential is conserved in the core conductor at all branching points. In the model, exergy loss and entropy generation rates are calculated for each branch of equivalent cylinders of electrotonic length (L) ranging from 0.1 to 1.5 for four different dendritic branches, input branch (BI), and sister branch (BS) and two cousin branches (BC-1 & BC-2). Thermodynamic analysis with the data coming from two different cat motoneuron studies show that in both experiments nearly the same amount of exergy is lost while generating nearly the same amount of entropy. Guinea pig vagal motoneuron loses twofold more exergy compared to the cat models and the squid exergy loss and entropy generation were nearly tenfold compared to the guinea pig vagal motoneuron model. Thermodynamic analysis show that the dissipated energy in the dendritic tress is directly proportional with the electrotonic length, exergy loss and entropy generation. Entropy generation and exergy loss show variability not only between the vertebrate and invertebrates but also within the same class. Concurrently, single action potential Na⁺ ion load, metabolic energy utilization and its thermodynamic aspect contributed for squid giant axon and mammalian motoneuron model. Energy demand is supplied to the neurons in the form of Adenosine triphosphate (ATP). Exergy destruction and entropy generation upon ATP hydrolysis are calculated. ATP utilization, exergy destruction and entropy generation showed differences in each model depending on the variations in the ion transport along the channels.

Keywords : ATP utilization, entropy generation, exergy loss, neuronal information transmittance
Conference Title : ICSRD 2020 : International Conference on Scientific Research and Development
Conference Location : Chicago, United States
Conference Dates : December 12-13, 2020