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Tuning chaos in network sharing common nonlinearity

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ABSTRACT

In this paper, a novel type of network called network sharing common nonlinearity comprising both autonomous and non-autonomous oscillators have been investigated. We propose that these networks are robust for operating at desired modes i.e., chaotic or periodic by altering the *v–i* characteristics of common nonlinear element alone. The dynamics of these networks were examined through numerical, analytical, experimental and Multisim simulations.

1. Introduction

Chaotic networks which are spatially extended have been special interest of research due to its wide applications in various fields such as hydrodynamics, model neural networks describing biological and artificial neurons, secure communication and so on. The mechanism of information transfer, cognition in brain and splitting of information from the central processing unit to the individual nodes can easily be conceived by correlating it to the dynamical properties of chaotic networks. Many rich phenomena could be observed in such complex systems including spatiotemporal patterns [1,2], chimera states [3,4], synchronization [5,6], amplitude death [7,8] and so on.

Recently, in an attempt to share nonlinear element among two forced dissipative LCR oscillators, Santhiah et al. [9] observed complex periodic orbits with the incommensuration of two or more frequencies and in the present study, we report the suitable modifications required for the Common Nonlinear Element (CNE) to set the network of periodically driven and autonomous oscillators in chaotic mode. These kind of networks can unveil many underlying phenomena of star network topology where all the oscillators are connected to the central hub.

In such a way, one can bring out chaotic dynamics in desired number of oscillators present in the network by altering the *v–i* characteristics of the CNE. Neural networks are akin to the considered model in the sense that it releases the same set of neurotransmitters to all of its synapses. From communication point of view, the lenient nature of this considered model to be operated at desired modes namely chaotic or periodic, makes it suitable for intelligent communication schemes. Whenever the oscillators in network follows the periodic regime, they suits well for conventional communication systems assuming every oscillators as the nodes among which the information transfers and once they are in chaotic mode robust secure communication is quite possible. A course of action to consummate chaotic dynamics in this assumed network of oscillators is to consider parameters for which the uniform oscillations of the network become unstable. When the number of breakpoints in *v–i* curve of the CNE increases then there is an increase in number of unstable equilibrium points in the system which would raise the strength of nonlinearity. Thereby, *slopes* and *breakpoints* computed from the driving point characteristics of the nonlinear element plays

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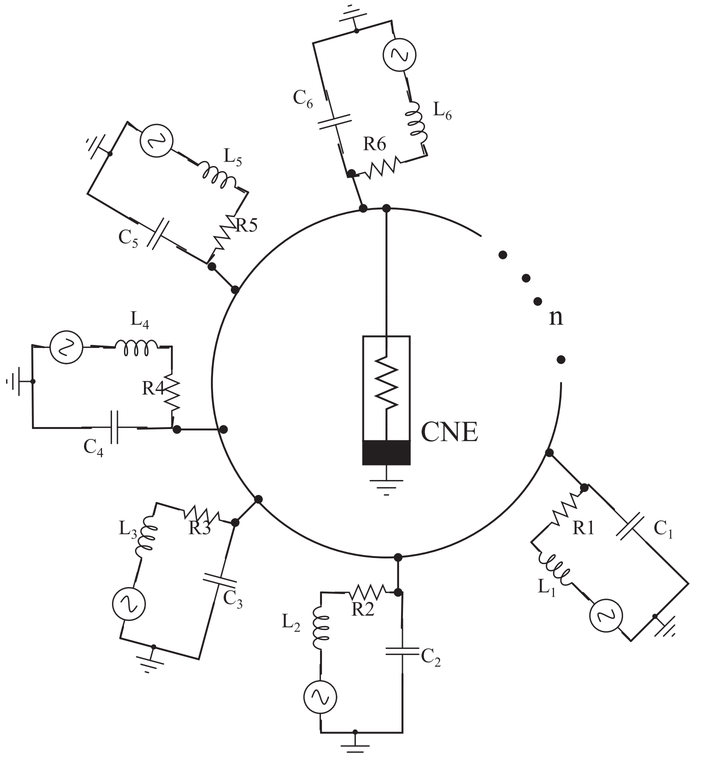

Fig. 1. Network of forced LCR oscillators sharing common nonlinearity.

a vital role in the chaotification of the considered network of oscillators. Nonlinear *v–i* characteristics of the several other electronic components are hard to control and hence achieving desired breakpoints and slopes is a herculean task. Hence parallel combination of Negative Impedance Converters (NICs) are chosen as CNE and their piecewise linear nature suits it for easy mathematical tracking. Upon changing the values of imposed resistors in NIC, one can adjust the location of breakpoints and slopes of each of the segments. Precisely, strength of nonlinearity is employed here as a tool for tuning and controlling chaos in the network of oscillators. How the *v–i* characteristics of parallel combination of NICs can be tailored in order to achieve chaos in network of oscillators sharing common nonlinearity is lucidly presented in this manuscript. Several other phenomena such as spatio-temporal dynamics, traveling waves can also be ascertained from this network but are beyond the scope of the present work.

Rest of the paper is organized as follows: Section 2 deals with the modification required for the common nonlinear element to set up to eight oscillators in chaotic mode. The role of common nonlinearity in forced LCR oscillators and the dynamics of them are scrutinized by numerical and analytical studies. In Section 3, study on the network of autonomous oscillators under the influence of CNE is elucidated using numerical and simulation techniques. Finally conclusions are given with the fine grasp of our observations in Section 4.

2. Non-autonomous model

2.1. Common nonlinear element (CNE)

Our proposed network of LCR oscillators with oscillatory input sharing common nonlinear element is depicted in Fig. 1. All oscillators are connected in such a way, that they receive equal potential from CNE. Forced LCR oscillators are promising candidates to exploit various underlying phenomenon of biological networks since, they mimic the dynamics of the same. These network of oscillators may be analogous to the cortical cells on the surface of cerebrum provided the electrical signals from CNE representing the thalamic input to the brain [14]. To start with, let us consider a simple configuration of single linear oscillator with CNE. For instance, to bring out chaos in one forced oscillator, single NIC can be used as the nonlinear element with the configuration of $R_1 = R_2 = 2.7\,k\Omega, R_3 = 800\,\Omega$. Breakpoints ($\pm$ 2.36 V) and the slopes (outer positive ($m_0 \approx 1/R_1$) and inner negative ($m_1 \approx -1/R_3$)) can be noted down from the driving point characteristics of NIC (Fig. 4(i)) and this configuration is verified in next section via numerical and experimental studies. In order to extend the idea of sharing nonlinearity among eight oscillators, the number of parallely connected NICs in CNE has to be modified accordingly (Fig. 2). Chaotification of oscillators sharing nonlinear element is quite possible by subsequently altering the CNE with respect to the number of oscillators in the network. Having fixed the values of the components used in the oscillators and by tuning the values of resistors in NICs alone, the number of NICs required to set the oscillators in chaotic mode can be determined. The relation between the number of oscillators