Chapter 27
Application of Mathematical Modeling for the Secure and Intelligent Energy Infrastructure

Tianxing Cai
Lamar University, USA

ABSTRACT

The unpredictable damage caused by potential attack and natural disaster may impact the operation of energy infrastructure, which is vital to local and national security. Thus, mathematical modeling based decision making tools become a must, because they can provide the scientific strategy to enhance the security and intelligence of energy infrastructure. In this chapter, the preliminary framework of a mathematical model is introduced. It includes the definition and characterization of energy network with the capability of self-recovery and the efficacy of the road map generation to handle the uncertainty of identified damage. The new methodology is the preliminary study for the future work in this field.

1. INTRODUCTION

According to Macmillan Dictionary, the definition of national security is "the protection or the safety of a country's secrets and its citizens" (Macmillan Dictionary, 2015). Therefore the purpose of national security is National security is to require the government and its parliaments to protect the state and its citizens against all kind of national crises. The common elements of national security are military security, political security, economic security, environmental security, security of energy and natural resources, cyber-security, empowerment of women (Romm, 1993; Paleri, 2008; Lippmann, 1943; Buzan, Wver & Wilde, 1997; Diamond, 2010; Rollins, John, & Henning, 2009; Lemmon, 2013; Devanny & Harris, 2014; Davis, 2010; Taylor, 1974; US NATO Military Terminology Group, 2010; Obama, 2010). Energy security is the combination between national security and the accessibility of natural resources for energy consumption. The development of the economical market and industrial operation are always requiring the utilization of cheap energy as much as possible. However, the unbalanced distribution of energy supplies in the regional and global wide has led to significant vulnerabilities.

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The long-term solutions to enhance energy security have included the methods to reduce dependence on the energy source which is imported from the other countries, grow the supplier team, and exploit indigenous fossil fuel or renewable energy resources, and decrease the demand by energy conservation. The short-term solutions to enhance energy security are trying to satisfy the availability and consumption of petroleum, natural gas, nuclear power and renewable energy. Thus, the energy infrastructure is vital to local and national security. The potential attack and natural disaster may impact the energy security. Since the loss or damage quantity is very difficult to be predicted or even cannot be predicted, the following and corresponding rescue will be delayed and this will raise the public safety threats. Therefore qualitative and quantitative decision making tools, which rely on the historical expert system and the mathematical modeling, are becoming more and more necessary because they can provide the reasonable and scientific analysis and optimization in the energy security enhancement and energy infrastructure intelligence. In this chapter, the preliminary framework of mathematical model will be introduced. It will include the definition and characterization of energy network with the capability of self-recovery and the efficacy of the road map generation to handle the uncertainty of identified damage.

2. RESEARCH PROGRESS

The scholars and researchers from the government, universities and research institutes have proposed the potential mathematical models which can be used to simulate and achieve the target of the uninterrupted availability of energy sources at an affordable price". The models will consider long-term energy security (timely investments to supply energy for economic developments and environmental sustainability) and short-term energy security (the capacity and capability of the energy system to provide emergency response to sudden changes within the supply-demand balance).

Markandya and Pemberton provided a framework to analyze energy security in an expected utility framework (Markandya & Pemberton, 2010). Their contribution can be further applied to handle the risk of disruption of imported energy. Their analysis has disclosed that the importance of an energy tax as a tool in maximizing expected utility, and how the level of that tax should be manipulated based on the values of key system parameters such as risk aversion, probability of disruption, demand elasticity and cost of disruption.

Bazilian, Rogner, Howells, Hermann, Arent, Gielen, Stedutof, Muellerf, Komorg, Tolh and Yumkella (Bazilian, et.al., 2011) have looked at the potential concerns in the area of energy, water and food policy. These issues can involve the problems of not only ensuring access to services but also environmental impacts to price volatility. Their study has provided the identification of these interrelationships, which is important to help target synergies and avoid potential tensions. They have presented the description of some of the linkages at a high-level of aggregation, some promising directions for addressing the nexus, the attributes of a modeling framework that specifically addresses the nexus, and the supporting information for more effective national policies and regulations.

Clastres (Clastres, 2011) has stepped into the field of interdisciplinary research in the deployment of smart grids in electricity systems. The technology itself will help to promote competition, increase the safety of electricity systems and combat climate change. However, the authors have disclosed many raised economic questions during the boom in smart grids. Based on their study, the public policies