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Stability Analysis of Network Control in Smart Grids using SMC: A Review

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Abstract: *In this paper, various methods for stability assessment of a smart power system is proposed. The key to this assessment is an index called between's index which is based on ideas from complex network theory. The proposed between's index is an improvement of previous works since it considers the actual real power flow through the transmission lines along the network. Furthermore, this work initiates a new area for complex system research to assess the stability of the power system*

Keywords*: Transient stability, complex network, smart grid.*

I. Introduction

Electrical energy systems all over the world have been undergoing unprecedented level of transitions in recent times. The transitions are primarily driven by the requirement to renew the aging electricity infrastructure; to integrate low-carbon intermittent energy sources; to meet increased power consumption and new forms of demands such as electric transport, smart home and business; and to ensure the security of supply. Several enabling technologies such as power electronics, wide are a measurements (WAMS) and the information and communication technology (ICT) are increasingly getting deployed in the system to deliver the requirement. Such deployments increase the complexity and challenges of the system operation and the electricity grid of the 21st century has to embrace these challenges through planning, design, operation and control. In the operation time-scale ensuring the security and stability of the system are important tasks. The WAMS and ICT offer very effective means of delivering these objectives ([1] and [2]). The networked control system (NCS) approach utilizing modern measurements and communications is very appropriate in this context. In NCS the control loops are closed through a real-time network where the control and feedback signals are exchanged among the system's components in the form of packets of data and information [5]. It enables execution from long distance by connecting cyberspace to physical space. It has been successfully applied in other technology are as such as space and terrestrial exploration, aircraft, automobiles, factory automation and industrial process control.The Packet-switching based communication networks are the most widely adopted systems for fast, economic and stable data transfer over both large and small distances through dynamic path allocation. They are in contrast to the traditional circuit-switching based networks in which a dedicated link is established between the sending and the receiving ends.Circuit switching is not only inefficient and costlier than packet-switching, but also the link failure rate increases for large transmission distances, and the failure cannot be dynamically corrected, unlike packet-switching [3], [4]. This is the reason that most of the current research in NCS is based on packet-switching technology. The NCS offers many advantages over the traditional control architectures, including low cost of installation, ease of maintenance and greater flexibility.They also suffer from some problems such as packet-dropout, network induced delays and packet-disordering [6]. These factors can possibly degrade the performance of the control of important power system dynamics such as system wide electromechanical oscillations, more commonly known as *inter-areaoscillations* of the system [7]. In the context of interconnected power systems, the control of oscillatory stability is very time critical as uncontrolled oscillations in the past have led to several power blackouts [8]. Therefore one needs to analyze these factors thoroughly for assessing the suitability of the NCS approach to wide area control of power systems.

Over the past decade, substantial research has been undertaken to model NCS and study the effect of packet-dropout and time delays on the control design and the stability of the NCS ([5], [6], [9] and [10]), but this research is not reflected in the power system literature. In most of the literatures relating to power systems, it is assumed that the transmission of signals to and from the central control unit occurs over an ideal, lossless and delay-free communication network. A few exceptions to this are [11], [12] and [13]. In [11] the effect of network induced time-delays has been considered using a WAMS based state-feedback control methodology. In [12] an estimation of distribution algorithm (EDA) based speed control of networked

DC motor system has been studied; and in [13] the effect of communication-bandwidth constraints on the stability of WAMS based power system control has been studied. But all these papers have other limitations. For instance, in [11] it is not explained how the various system states (such as the rotor angle, rotor velocity and transient voltages) are estimated before using them for state-feedback; and also the power system model considered in the paper is too simplistic to represent actual power system dynamics. In [12] only a local network based control of a single dc-motor system is considered instead of considering the networked control of a complete power-system. In [13], the chief problems associated with networked-control, which are packet-loss and delay, are not considered.Transient stability of power systems has been addressed many times through developing various control techniques which can be categorized as centralized, decentralized, and distributed approaches. The centralized controllers act upon receiving state information from remote

nodes, calculate, and transmit the control signal to the actuator located near synchronous generators. While the excessive communication needs make them inefficient in terms of latency, controlling the power system from a single point causes security flaw.
The rest of research paper is design as follows. The overall previous work is described in Section II. Section III describes problem formulation. performance parameter describe in section IV. Finally, Section V describes the conclusion of paper.

II. Literature Review

This section will provide the brief description and highlights the contribution, remarks and factors of the work done by the researchers. Many attempts have been made in the past to achieve clustering coefficient.
Bo Chen, Salman Mashayekh et. al (2016) presented major concern of smart grids, as the functionality of a smart grid is highly dependent on the cyber communication. Therefore, it is important to study the impact of cyber-attacks on smart grids. This paper discusses several types of cyber-attacks. [1].
Soheil Derafshi Beigvand et. al (2017) investigated distribution smart grids (SGs) are very important due to the increased penetration of distributed energy resource making bidirectional flow of electric power. This paper presents two novel fast voltage stability indices (VSIs) applicable to the radial distribution SGs based on the real-time measured voltage data only, obtained by the SG infrastructures such as smart metering device[2].
Abhinav Kumar Singh et. al (2016) defined suitable networked control scheme and its stability analysis framework have been developed for controlling inherent electromechanical oscillatory dynamics observed in power systems.The closed-loop stability analysis framework has considered the limiting probability of data dropout in computing the stability margin. The research findings are useful in specifying the requirement of communication infrastructure and protocol for operating future smart grids. [3].
Diptargha Chakravorty et. al (2015) proposed small signal stability analysis of distribution networks with electric springs (ESs) installed at the customer supply points. The focus is on ESs with reactive compensation only. The impact of distance of an ES from the substation, proximity between adjacent ESs and the R/X ratio of the network on the small signal stability of the system is analyzed and compared against the case with equivalent DG inverters. The collective operation of ESs is validated through simulation study on a standard distribution network [4].
Shichao Liu et. al (2014) proposed great potential to improve the overall performance of data transmission with its dynamic and adaptive spectrum allocation capability in comparison with many other networking technologies, cognitive radio (CR) networking technology has been increasingly employed in networking and communication infrastructures for smart grids The sufficient conditions are obtained for the stability of the AGC of the smart grid with these two CR networks, respectively. Simulation results show the effects of the CR networks on the dynamic performance of the AGC of the smart grid and illustrate the usefulness of the developed sufficient conditions in the design of CR networks in order to ensure the stability of the AGC of the smart grid. [5].
M. Ayaret.al (2016) investigated increasing deployment of information technologies and low inertia renewable energy sources into smart grid fuel the uncertainties and reveal security and transient stability problems. The simulation results validate the feasibility of the proposed control framework and robustness under cyber-physical practical limitations.. [6].
Ahmad F Taha et.al (2014) proposed unknown Input Observers (UIO) use the known plant's inputs and outputs to generate state estimates for plants with unknown inputs. The stability of the NetUIO is analyzed by deriving a stability-guaranteeing bound on the networked induced perturbation. Numerical simulations are provided to highlight the applicability of the obtained bounds. [7].
Petros Aristidou et. al (2014) presented case study dealing with long-term voltage instabilityin systems hosting active distribution networks (DN) is reported in this paper [8].
The simulation of various IEEE standard test systems using the method proposed in the paper and other methods used by earlier researchers show clearly that the proposed method is more realistic and draws a margin between stable and unstable region. Although, the proposed approach is simple, it provides a new direction for complex system network research. [9].
Y. Tipsuwan et. al (2013) proposed environmental concerns due to emissions from nuclear and fossil fuel based power plants have triggered widespread utilization of renewable energy-based small- and large-scale distributed generation technologies. This article analyzes various stability concerns in smart power grids pertaining to distributed generations and proposes novel methodologies for ensuring operational stability. Results of this research validate the necessity of coordinated control for maintaining stability of smart grids incorporating distributed generation technologies. [10].
J. Hespanha et. al (2013) analyzed Smart Grid and Renewable Energy technologies are an important issue with regards to global cli-mate change problem and energy security. The evolution of current conventional or centralized generation in form of distributed generation and Smart Power Grid (SPG) has great opportunity This paper explores Smart Grid technologies and distributed generation systems. Furthermore, it discusses the impact of distributed generation on Smart Grid, particularly its system stability after installing distributed generation in the Smart Grid[11].
S.Wang et. al (2012) proposed interconnected power systems always operate close to stability limits. Increased penetrations of renewable resources have made the situation worst. Thus it is indeed important to develop understanding of the phenomenon through reviewing various case studies in literature. This paper explore the initial review on understanding the voltage collapse phenomena, identification of weak nodes, synchrophasor technology based voltage collapse detection and control [12].

III. Problem Formulation

In recent years major black outs around the world has been reported due to voltage instability. Reasons for the problems of voltage stability in power system are as follows; Large load or large disturbance in a heavily stressed power system. Large disturbance between generation and load unfavorable load characteristics, large distance between Voltage sources and load centers. low voltage profile, insufficient load reactive compensation. Action of ULTC during low voltage conditions and. Poor coordination between various control and protective systems. High reactive power consumption at heavy loads and unsuitable locations of FACTS controllers.

IV. Performance Parameter

This section describes some basic statistic parameter ofpower grid within complex network framework. All of theseparameters come from graph theory, the branch ofmathematics that deals with networks [29].

1. Degree

The number of links, directed or undirected, connected witha node *i* in a graph is called the degree of the node, *di* .When the graph is directed, the out-degreeof a node is equal to the number of outward-directed links, andthe in-degree is equal to the number of inward-directed links.The hub of a graph is the node with thelargest degree.

2. Clustering Coefficient

Every node directly connected with a given node is called the neighbor of that node. If there are *di* such neighbors of a node *i*, it means that there may be *[di(di-1)]/2* potential links among the neighbors of the node *i.* Suppose that the neighbors share *c* links; then the clustering coefficient of node *i*, *Cc(i),* is the ratio between actual number of links and maximum possible links.

$$\text{Cc(i)} = \frac{2c}{d_i(d_i-1)}$$

The clustering coefficient of an entire graph is the average over all node clustering coefficients. If there are *n* nodes in the whole system the clustering coefficient of the whole system or graph *G, CC(G),* is

$$\text{CC(G)} = \frac{1}{N}\sum_{i=1}^{N} Cc\ (i)$$

3. *Characteristic Path Length*

The length of a path is equal to the number of links between starting and ending nodes of the path. Path length is measured in hops the number of links along the path. The distance between two nodes along a path is equal to the number of hops that separate them. [3].

V. Conclusion

In this paper, we demonstrated the use of complex networktheory for vulnerability analysis of power systems into considerations actual electrical parameters. Thesimulation of various IEEE standard test systems using themethod proposed in the paper and other methods used byearlier researchers show clearly that the proposed method ismore realistic and draws a margin between stable and unstableregion. Although, the proposed approach is simple, it providesa new direction for complex system network research.

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