Employing the Pre-Existing Direct Methods and New Techniques in Analyzing Stability of Power System: A Review

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***Abstract*: With the consistent increment in electric load, power generation must increment at a comparable rate to stay aware of the request. Over the most recent couple of decades, the wellsprings of power generation were principally coal, atomic, and natural gas. As of late, in any case, it has turned out to be compulsory to incorporate a level of clean electric power generation. The Department of Energy has set necessities by 2030 to utilize renewable resources that don't deliver hurtful results, similar to CO2, coal fiery debris and atomic waste. While different wellsprings of renewable energy resources can be more productive, sun based energy can be ideal to use in specific areas when the measure of sun radiation is high and the cost of land is moderately cheap. One of the approaches to change over sun powered radiation into electricity is utilizing Photovoltaic (PV) cells.**

***Keywords*: electric load, power generation, natural gas, coal fiery debris, Photovoltaic**

I. Introduction

The regulation and monitoring of voltages were more and more complicated to schedule and run, especially in longitudinal networks, over the last few years. To order to satisfy the growing demand for energy, companies tend to focus instead of constructing new transmission lines on the current generation and production exports and import agreements. The need to optimize the usage of current transmission networks has been expressed in this. At the other side, the energy flows are far below their thermal limits in some transmission lines, while some lines are overloading which typically decreases the voltage profile efficiency and the reliability and protection of the network. However, in most situations, current conventional transmission networks do not fulfill the control criteria of advanced dynamically integrated power systems.

Bus voltages have to be regulated at a certain range in constant state. Adequate voltage and reactive power management allows voltages to be minimized, transmitting capacities to be effective and reliability margins to be improved. The general condition allows for the analysis of conventional communication technologies, modern ideas, and a redesign of their complete capability without compromising the reliability and protection of the networks. That involves utilizing current generation and transmission lines. The voltage regulation function at transmission rates can be accomplished by various control methods and operational procedures including the infusion of series or shunt voltage at critical power systems locations. An adjustment is made in the voltage network when interference happens and the reinstatement to the reference values relies on the complex reaction of the control equipment.

The transmission voltage must be higher than the receiving end in a control device network in order to retain a healthy power unit factor. If the voltage deviates, as seen in Figure 1.1, it has a finite duration and meaning that can be controlled by the device.

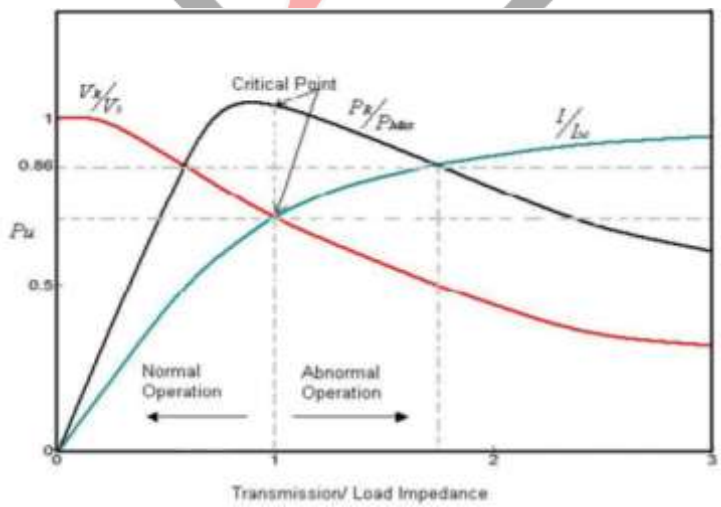

Figure 1. Operational limits of the system for voltage collapse

"The series of events that follow voltage instability in a power grid network contributes to a failure in a large portion of the electricity supply. Numerous network blackouts have recently been related to falling voltage. Recent outbreaks in the United States and Canada on 14 August 2003, in London on 28 August 2003, in Italy on 23 September 2003 and in Russia on 25 May 2005 and in Pakistan on 24 September 2006 have left the world very concerned about the nature of such outbreaks and their root causes and possible

solutions. Blackouts arise from instability, breakdown of voltage and maladministration of loads, of which reactivity may be regulated in a way. When either voltage variations or frequency instability can not recover from the network, instead generators must be wired off the grid in order to minimize disruption. This tendency appears to appear in extremely stressful environments as a function of the loss of reactive energy."

"Voltage failure has triggered many significant network failures in recent years. The possible effect of tensile instability is load failure in an environment, or the tripping, by the protective mechanisms of the transmission lines and other components, of cascaded outages and voltage collapses in the network. Specific studies for this issue were conducted. In recent times a variety of researches have been documented on new formulations that take into consideration the voltage stability issue owing to the need to have voltage stability limitations. However, the approaches achieved often become too expensive since all the viability and reliability constraints become addressed."

"The rapid development of power electronics technology provides an opportunity to develop new power equipment to improve the performance of the actual power systems. This made construction of modern Static Var Compensators (SVCs), Thyristor Controlled Series Capacitors (TCSCs), Thyristor Controlled Phase Angle Regulators (TCPARs) and many other power electronics based controllers possible. This concept and advances in the field of power electronics led to a new approach introduced by the Electric Power Research Institute (EPRI) in the late 1980 called Flexible AC Transmission Systems (FACTS), which provided a more efficient use of already existing resources in present power systems while maintaining and even improving power system security."

II. Review of Literature

Sahami et al., (2018) Timely information about behavior of a power system is important for monitoring and controlling the system. Accurate and prompt transient stability prediction is an effective way to reduce the risk of a power system failure and possible blackouts. In this paper, a method for predicting the generators behavior using Taylor Series has been derived that can be used to predict the angular changes during transient oscillations and thus the related critical clearing time. The paper also discusses the application of this approach for preventive control actions. The proposed technique is applied on IEEE 39 bus test system and the advantages, efficiency and error comparisons are presented."

Cecati et al., (2012) This paper attempts to study the transient stability of a two machine infinite bus system when affected by large disturbances, by comparison of time domain approach vs. transient energy function. Then the decentralized nonlinear controller is embedded within the power system and simulation results show that the transient stability has been greatly enhanced. Based on the existing transient energy function of uncontrolled power system, the controlled power system has been represented as a forced Hamiltonian system. The Lyapunov function which is suitable for transient stability analysis of this controlled power system has been used for stability assessment. Simulations in different operating points show the enhancement of transient stability of power system with controller in both time domain approach and energy function method."

Mariotto et al., (2010) this study presents an efficient method for estimating transient stability indices of electric power systems. It is based on equivalent network reduction techniques. The electromechanical equivalent system has been accomplished by considering clusters of coherent generators. The angular speed deviations of synchronous generators have been used as a criterion to perform the groups. The reduced order is obtained by replacing two groups of coherent generators by a single machine equivalent. With these equivalents, critical fault clearing times and security margins are calculated by using the well-known equal-area criterion. The method was compared with others, especially those based on the concepts of transient energy function. The critical fault clearing times are in agreement with and very close to those obtained by using Liapunov's direct method or the time-domain solution of the n -machine original system. Some numerical results are presented for a 3- and 10-generator power systems. The method is an excellent tool that can be applied as a filter to identify potentially harmful contingencies and to select these to perform detailed transient stability analysis."

Owusu-Mireku, Robert. (2018) in this paper, we propose an energy-based method for the transient stability analysis of a power system transmission switching event. In this method the exit point of pseudo-fault trajectory is used to determine a relevant controlling unstable equilibrium point (CUEP) for a switching event, the stability of the switching event is then assessed based on the energy margin between the computed relevant CUEP and the post-switching initial point. The effectiveness of the method is demonstrated on switching events in the structure-preserving models of a heavily loaded version of the WSCC 9-bus 3-machine system, and the base case IEEE 145-bus 50-machine system. A scheme for the detailed analysis of power system switching events is then proposed."

Priyadi et al., (2010) this paper studies new techniques for critical trajectory method, a recent new method proposed by the authors for obtaining critical clearing time (CCT) for transient stability analysis. A specific feature of the proposed method lies in its ability to provide exact CCT without approximations since no such methods have existed so far. The method is based on the computation of the critical trajectory, which is defined as the trajectory that starts from a point on a fault-on trajectory at CCT and reaches an end point. There are a few possible methods for the treatment of the end point conditions, computational performances of the methods are investigated in terms of accuracy of CCT and computational efficiency. It is shown that the proposed methods successfully provide the exact CCT that agrees with the conventional numerical simulation method."

Benidris et al., (2016) this paper addresses the effects of transient instability on power system reliability. Composite system reliability evaluation has been performed based on steady-state estimation of load curtailments. In composite reliability evaluation, after each contingency, faulted components are assumed to be isolated from the rest of the system immediately and the system is assumed to return to a stable state with proper generation rescheduling for minimum load curtailments. In this context, minimum load curtailments are usually performed by solving linear/non-linear programming optimization problems. Although the optimization problem with minimum load curtailment may find a steady-state feasible solution, a stable transition to a post-fault stable equilibrium point is not guaranteed. In this paper, three probabilistic transient stability indices are proposed to assess system robustness against transient contingencies and update the reliability indices. Transient stability direct methods are used in assessing

system stability and determining the probabilistic stability indices. This method is applied on the reduced WECC (Western Electricity Coordinating Council) system and the results showed that the effect of transient instability should not be ignored."

Rygg et al., (2016) In this paper a new method for power system stability analysis is introduced. The method is based on injection of a small voltage or current in an arbitrary point of the system. The apparent impedance is defined as the ratio between the voltage and current in the injection point. It is shown that the apparent impedance can be used to estimate the eigenvalues of the system that are observable from the injection point. The eigenvalues are obtained by applying the Vector Fitting algorithm to the measured set of apparent impedances. The proposed method holds some advantages over the well-established impedance-based analysis method: It is no longer needed to estimate the source and load impedance equivalents separately, and it is not necessary to make any assumption regarding where the source and load are located. This reduces the required measurements and data processing. Furthermore, the stability analysis is global in the sense that the resulting stability margin does not depend on the injection point location. Finally, the method is well suited for real-time implementation due to low computational requirements. The method is outlined for DC-systems, while further work will extend the theory to cover single-phase and three-phase AC systems."

Hidayat et al., (2018) there are two factors that must be considered for the power quality analysis of an electrical power system, i.e. frequency and voltage stability. The system that can return to the initial condition or the steady state after a disturbance occurred indicates that the system is stable. This paper aims to detect the transient stability of three generators, which have identical specification of 2.25 MW 6.6 kV and are operated in parallel, based on the frequency performance. In this paper, the stability analysis is determined by using the nyquist method, where the system stability is indicated by the value of the response curve of the system. The analysis results show that the system of three paralleled generators have the value that far from 1 + j0 and the phase margin value and gain margin tend to be minimum. These values indicate that the system is unstable. The system slowly changes into more unstable because the oscillations are getting bigger until the final state. So, it is necessary to change the parameters of each generator that can affect the system stability during synchronization state."

Naji et al., (2014) a transmission line trip during a power swing may cause instability of a power system. It is necessary to recognize the power swing from fault based on stability boundary, the power swing blocking relays must be set to do that, power swing should be analyzed, a way of probability of occurrence of fault must be found, the critical recognized & finally the settings of the power swing relays are calculated. The main aim of this paper is to reduce the execution time of the process of finding of the Critical Clearing Time (CCT) using Programming Fast Method (PFM) and compare it with Bisection Method. In practice however, calculating the CCT is computationally inefficient and not desirable because the Bisection method is a tedious and inefficient process. A proposed method for finding the CCT of the power system at any direct fault or indirect-fault is more efficient method in the accuracy & solution time to calculate (CCT) in transient stability analysis. The results obtain by Bisection and proposed methods show that the proposed method reduce the execution time of the CPU about 8-10 times. In this paper the CCT was calculated for two power systems (single machine and the Iraq Super Grid at 10 locations in the Iraqi transmission line network) by using Bisection & proposed methods. MATLAB version 7 is used to implement several programs for the optimal execution time of the CPU time, with using PC4 and CPU speed 3 GHz."

Yorino et al., (2010) this paper proposes a new formulation for transient stability analysis for electric power systems. Different from existing methods, a minimization problem is formulated for obtaining critical clearing time (CCT) for transient stability. The method is based on the computation of a trajectory on the stability boundary, which is referred to as critical trajectory in this paper. The critical trajectory is defined as the trajectory that starts from a point on a fault-on trajectory at CCT and reaches a critical point of losing synchronism. The new proposal includes a modified trapezoidal formulation for numerical integration, the critical conditions for synchronism, and the unified minimization formulation. It will be demonstrated that the solution of the minimization problem successfully provides the exact CCT that agrees with the conventional numerical simulation method."

Chen, Shengen. (2017) In order to assess the reliability of power systems, transient stability simulations must be conducted in addition to steady state study. The transient stability component of reliability studies usually involves extensive simulations generating large amounts of data to be analyzed. Conventional stability analysis relies on a visual examination of selected simulation data plots to classify the severity of disturbances. This conventional examination, which aims to compare the simulations results to established performance criteria, is not comprehensive, is time consuming and prone to subjective interpretation. This paper presents a quantification method for power system performance evaluation. It applies a range of criteria such as rotor angle separation, loss of source, damping, and voltage sag directly to the simulation data files to achieve a more efficient and objective stability assessment. By using stability modules, the proposed method evaluates the performance of every fault location, numerically, by providing a local stability index, as well as an overall global stability index. The method also provides an evaluation of dispatches and their impacts on system stability. The IEEE 39-bus test system and the Northeast Interconnection Power System were used to show the results of this method. This method will free engineers from tedious, time-consuming and error-susceptible offline visual analysis and yield significantly quantified results."

Salam et al., (2014) Transient stability analysis plays an important role for planning, designing and upgrading an existing electrical power system network. In this paper, transient stability analysis is carried out by considering a three-phase fault at the busbars 7 and 4 with the effect of various fault-clearing times. The simulation is carried out using CYME 5.02 power system software with fast decoupled method. It is found that at fault clearing times of 0.05s, 0.1s, and 0.15s, the generators (G2, G3) under test are stable with respect to the simulation time. Whereas, at fault clearing times of 0.2s and 0.3s, these generators are found to be unstable for both faulted busbars 7 and 4. These simulation results are then compared with the proposed model results and are found to be in good agreement. In addition, it has been demonstrated that the transient stability of a system can be improved using control devices."

Hu et al., (2017) Stability is an important element to be considerate in the design and analysis of isolated power system. Due to the conservatism of the existing stability criterion, which makes the isolated power system cost a lot for stable operation. Tighter restrictions are also put forward for system cascade. In this paper, consider the gain margin and phase margin constrain at the same time and deduce the stability criterion with smaller forbidden region to calculate generalized impedance constraint set and

generalized load admittance set of the multi operating point system. An isolated power system consisting of a synchronous machine with a rectifier as a source and a constant power as load is analyzed by using the proposed method and which compared with existing method shows it can get more accurate results and reduced conservatism effectively.

In **Klein et al (2011)** Grid associated sun oriented photovoltaic generation can acquaint a few unforeseen conditions with the system like voltage fluctuation in appropriation feeder, high transmission and circulation misfortunes, over-burdening, presenting of gleam and music and so on. Photovoltaic generation has some similar points of interest over breeze generation. Despite having high introductory speculation, the sun oriented PV generation turns out to be progressively alluring to most create and a portion of the creating nations in later past and the aggregate generation by photovoltaic system is expanding step by step.

In **Smith et al (2011)** Effects of photovoltaic systems on dispersion systems have been the subject of many research examinations. These examinations to a great extent center around the conduct of the system while PV generation resources are associated with the matrix, as far as the area of the association point and control procedures that could be considered for better system execution. The majority of these exploration endeavors are directed for appropriation systems since the level of PV establishments is thought to be sufficiently little to have a less huge impact on the transmission system. With more PV establishments, high PV entrance has been as of late granted more consideration among scientists. Progressing considers explore the impact of these systems on the power conveyance systems.

In **Zhang et al (2010),** It has been appeared in that, contingent upon the measure of PV sunlight based generation and the purpose of interconnection (POI), transient voltages could have preferable or more awful conduct over the case without PV. Albeit the vast majority of these investigations show that high PV infiltration can effectsly affect system homeless people, the cases considered for system examines are not genuine portrayals of a bigger, interconnected power system.

III. Conclusion and future work

We start with presenting the well-established energy function theory and the characterization of stability boundary under certain assumptions which led to the popular direct method of BCU. We use this method to do a parametric study on locational inertia reduction resulting from displacement of conventional units by PV with is effectively a zero inertia machine. A method was proposed to visualize approximately the changes in stability boundary with inertia changes using the BCU results for larger systems. It was seen that the displacement among generators having a significant participation in the disturbance under study negatively impacted the transient stability of the system. This was followed by a study in which the conventional generation re-dispatch was varied as a parameter to accommodate a fixed amount of PV in the system. The PEBS which under most conditions gives the intersection of SR with the $\omega = 0$ plane was plotted against the parameter. It was observed that the increasing under-loading of generators to accommodate PV increased the relative distance of the stability boundary from the SEP. This confirms that original hypothesis of increasing stability with decreasing loading. The overall conclusion to be drawn from these two studies was that unit commitment would be a serious problem from the point of view of stability for systems with high penetration of PV.

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