Voltage Instability Prediction Using Artificial Immunity System

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Abstract— A newly developed technique for Artificial Immunity System (AIS) based voltage instability detection during transient period is presented in this paper. The AIS technique is developed to predict the system behavior and determine voltage instability occurrence. The voltage instability is analyzed and studied using the concept of Wide Area Measurement Protection And Control (WAMPAC). The concept of WAMPAC provides better chances for protecting the system against faults. It gives the opportunity of having various amount of information from different locations. Phasor Measurement Units (PMUs) plays an important role as part of WAMPAC system. It helps in predicting voltage instability of synchronous generators. A developed Artificial Immunity System (AIS) is designed and tested to predict system voltage instability. The work is progressed through three main stages. First stage is the electrical system simulation and execution utilizing Power System Analysis Framework (PSAF) program. Different types of faults in different location are applied to the system. Second stage is the data handling and processing unit.The generators' bus voltage magnitudes and angles are handled and processed. Finally AIS technique is developed to differentiate between voltage instability and normal cases.The AIS technique is programmed using MATLAB. The newly developed approach generates a defense strategy which answers the following inquiries: a- detecting abnormal condition, b- reporting System Protection Center (SPC).The proposed system is applied to the IEEE 14 – bus system. It produces good results in mitigating voltage instabilities of power system.

Index Terms— Artificial Immunity System (AIS), Artificial Intelligent (AI), Phasor Measurement Unit (PMU), Power Systems Analysis Framework (PSAF), System Protection Center (SPC), Voltage stability,Wide Area Measurement Protection And Control (WAMPAC).

1 Introduction

One of the vital electrical power requirements is a reliable uninterruptable power system service without sudden blackout occurrences. Generators' voltage instability Studies are important to insure continuity of service. Voltage stability defines as the ability of power system network to keep steady state voltage at all buses after disturbance. As a result, measuring and controlling voltage become vital tasks to protect power system networks against voltage instability. Phasor Measurement Unit (PMU) achieves colossal success in the measurement field, which greatly helps in system protection and faults detection technologies. The use of phasor technology started in the 80's with the early pioneering work done by Bonneville Power Administration [1].

In 2003 Eastern USA Interconnection blackout took place. It highlighted the need for technologies that provide wide area studies, analysis and monitoring [2]. The timesynchronized data became accepted by the industry. PMU can be used for a lot of purpose such as monitoring, visualization and disturbance analysis. The existence of PMU helps in building great monitoring systems. It gives the opportunity to WAMPAC concept to be applied and developed. WAMPAC and PMU help Protection Center to take suitable action to avoid blackout of the system. Artificial Intelligent (AI) techniques improve dealing with the concept of WAMPAC, since they can handle different types of data easily. AI techniques can solve different types of problems, such as pattern recognition problems, control and optimization problems ... etc. The original vision of AI was developed by monitoring the capabilities in humans. By the late 1980s, that situation started to change. Subfields as machine learning, and planning began to be broken away from AI, establishing their own conferences, journals, and criteria for progress [3].

Today there are different types of artificial intelligent systems. Each type has its own advantage with better performance in certain application. The biological immune system is a robust, complex, adaptive system that defends the body from foreign pathogens [4]. In 1986, farmer Packard and Perelson's started building an artificial intelligent system based on the immune of human body. It is called Artificial Immunity System (AIS) [5].

In this paper, a new approach for Artificial Immunity System (AIS) based voltage instability detection during transient period is developed. The newly developed voltage instability detector is applied to the IEEE 14 bus system. It shows acceptable results in expecting system behavior.

2 Detection of Voltage Instability

It is very important to study the difference between sudden and major changes as factorsthat affect stability of synchronous generator. Large disturbance occurrence causes the network characteristics to shrink dramatically. The load increases beyond the voltage collapse point, which results in loss of equilibrium of the power system. Multiple cases can occur concerning voltage instability case [6]. Some of these scenarios that can cause voltage collapse are:

1- When EHV transmission lines are heavily loaded, then generation capacity of the critical area is temporarily reduced.

2- When a heavily loaded line is lost due to a fault or any other reason. The loading and reactive power losses of remaining lines increase.

3- The increased reactive power demand increases the reactive output of the generators.

Since voltage stability is very important factor concerning synchronous generators, so a lot of effort is exerted to find ways for protecting the electrical systems against voltage instability. By studying the relation between transmitted power P, Reactive power and voltage at receiving end voltage stability can be determine. Figure 1 illustrates the relation between P-V curve and Q-V curve. When studying the relation between active power supplied to the load and voltage characteristic curve it is very important that the system doesn't go beyond critical point. In case of this happen the voltage will drop so rabidly which case instability condition. The variation in reactive power can affect the voltage at the load bus. Figure 1.b show the voltage stability limit. If the system goes beyond this limit reactive power will increase causing instability occurrence.

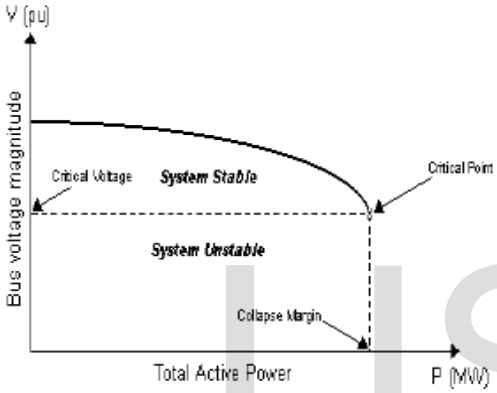

fig.1a Power voltage characteristic [7]

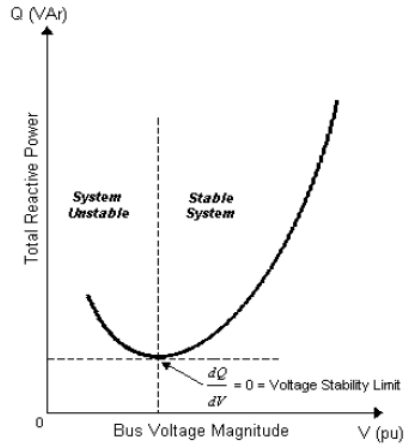

fig.1b reactive voltage characteristic [7]

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The power system transient study is simulated using Power Systems Analysis Framework (PSAF) program. PSAF provides an easy way to handle studies, networks and equipment databases. It allows creating and maintaining study cases. The suite includes programs for load flow, short circuit and transient stability analyses of electrical network.

The output of the PSAF simulated program is fed to a newly developed Artificial Immunity System (AIS) technique to be analyzed.

3 ARTIFICIAL IMMUNITY SYSTEM (AIS)

The immunity of human body is considered one of the most incredible and complicated process. Due to the human body immune accuracy, engineers work on simulating the process and applying it to different industrial fields. The AIS is featured from computational immunology and theoretical biology that is concerned with simulating immunology using computational and mathematical models for better understanding of the immune system [8]. The concept based on the ability of the system to differentiate between self and non self cell.

The idea of human body immune system depends on both antibody and antigen. T lymphocytes act as detector as it get activated when antigen enter body. T lymphocytes activation causes activation of B cells. B cell tries to build affinity with T lymphocytes through receptors, strong affinity form plasma cell. Memory cell will be generated so in case antigen appeared any time. Body will be able to identify it and produce the appropriate antibody, as shown in Fig. 2.

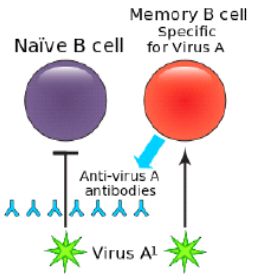

fig.2 Nature of Immune system [9]

The engineering researchers classify the AIS technique regarding the applications into three schools. The three schools are literal school, metaphorical school, and people who develop AIS system according to mathematical models. In this paper, artificial immunity technique is developed based on metaphorical schools. Metaphorical schools looks for inspiration from the immune system and build computational systems with the immune system in mind.

3.1 ARTIFICIAL IMMUNITY SYSTEM PREDICTOR

AIS developed technique acts as voltage instability predictor, as AIS study the generator behavior during transient fault

period.

The AIS predictor decides whether power system suffers from voltage instability or not according to the algorithm mentioned in Fig. 3. The voltage magnitude of each generator is compared with the stored data using the concept of minimum and maximum voltage limits for each generator. Once matching is found, the status of the generator can be determined. And the data related to the stored case is drawn in form of stability. Normal case represents antibody, while fault case represent antigen.

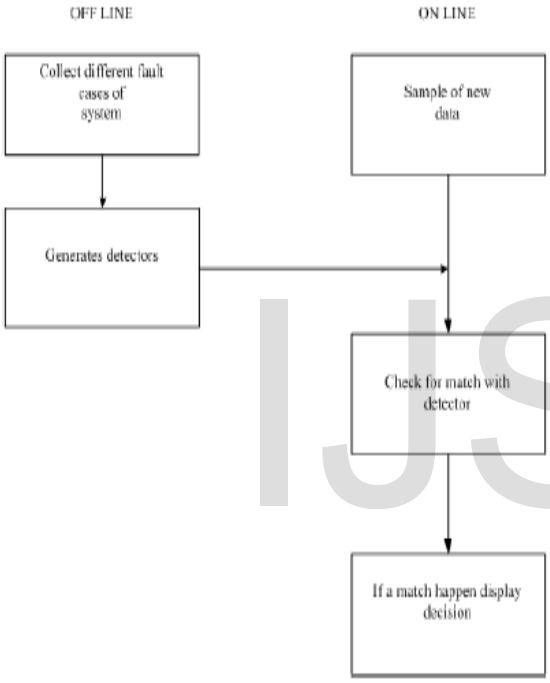

fig. 3 Flow chart of AIS predictor (metaphorical school)

4 SIMULATION AND RESULTS

The work is progressed through three main stages, which are summarized in the following block diagram of Fig.4. It is applied to IEEE 14-bus system.

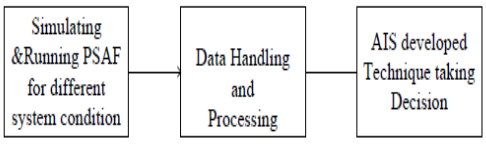

fig. 4 Block diagram of developed work

The three stages are;

First Stage: is simulating the IEEE 14-bus system (shown in Fig. 5) utilizing PSAF program, and running the system multiple times for different scenario. The IEEE 14-bus generators' data are illustrated in table 1 [10].

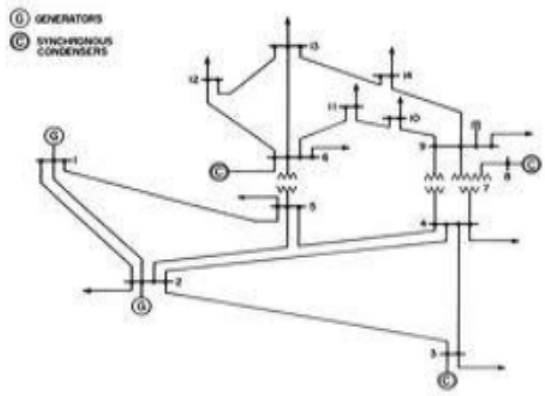

fig. 5 IEEE 14-bus standard systems [10]

Table.1 Generator parameter of IEEE 14-Bus system

Generator Parameters for the IEEE 14 Bus System

Generator	Bus	p_{sc} (MW)	$1/R$ (per unit)	M (per unit)	AGC Participation Factor
1	Bus 1	54	75	25	0.2
2	Bus 2	40	75	25	0.2
3	Bus 3	60	75	25	0.2
4	Bus 6	70	75	25	0.2
5	Bus 8	74	75	25	0.2

Second Stage: is the handling and processing of the PSAF output data through MATLAB program, to be used by the developed AIS program. PSAF output data presents the PMUs readings.

In Third Stage: finally, the newly developed AIS technique studies the system and takes decision whether the system suffers from voltage instability or not.

The previous mentioned steps are shown in the flowchart of Fig. 6.

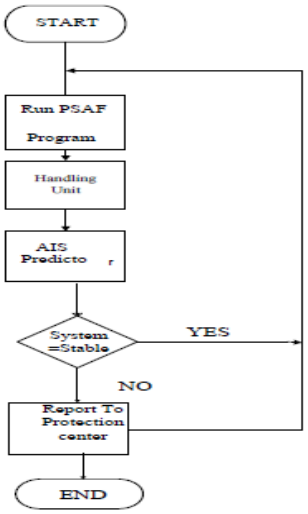

fig. 6 the flowchart of the developed AIS based system

After testing the newly developed AIS system on 40 different power system conditions, it shows high flexibility and gives efficient results. Some of these cases are discussed in details

CASE 1:

In this case, the proposed AIS is tested by applying fault to bus1 for 10 cycle. The fault is removed by disconnecting line 1-2. The developed technique succeeds in expecting that system doesn't suffer from voltage instability. Figure 7 shows the variation of the generators' reactive power versus their voltage. It illustrates that the system still stable, as all generators still operate in the stable range. Figure 8 verify through relation between reactive power and voltage that system is stable.

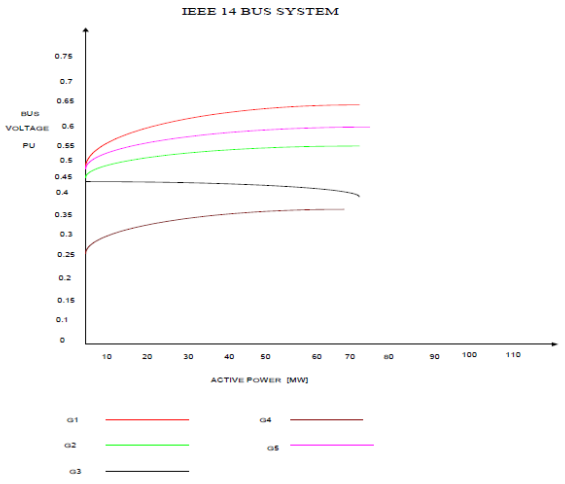

fig.7 P- V curves for generators bus after applying fault to bus1 and clearing it

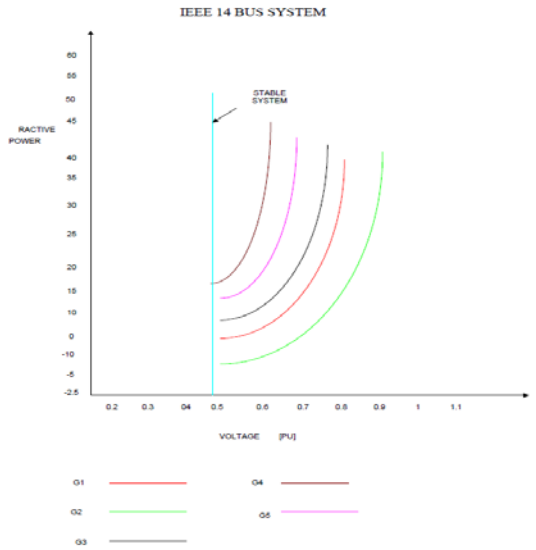

Fig.8 Q- V curves for generators bus after applying fault to bus1 and clearing it

CASE 2:

In this case, the proposed AIS is tested by applying cascaded faults on buses 1 and 2 respectively. The first fault cleared by disconnecting line 1-2 after 16 cycle, while the second fault cleared by disconnect line 2- 3 after 15 cycle. The newly developed technique illustrates the major changes that are happened to the system as presented in Fig. 9 and Fig 10. The system suffers from instability condition. The developed technique succeeds to reach a decision in 0.18 seconds which is considered to be a suitable time.

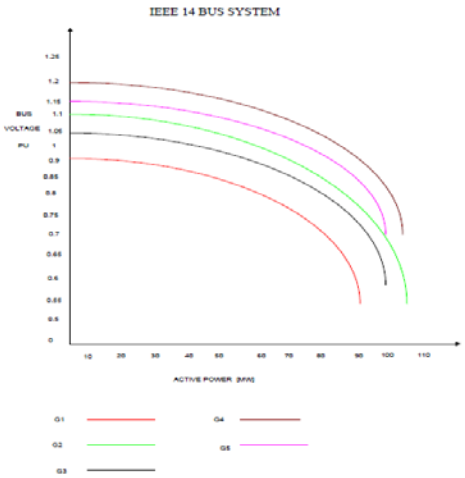

fig.9 P- Vcurves for generators bus after applying faults to Bus

1 and 2 and clearing it

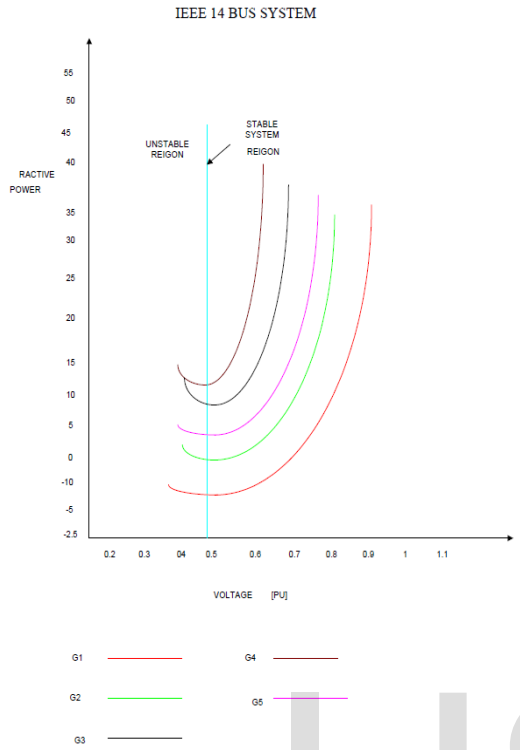

fig. 10 Q- V curves for generators bus after applying faults to Bus 1 and 2 and clearing

4 Conclusion

Electrical power systems continuity and reliability are considered to be main issues in efficient systems. A newly developed approach, utilizing AIS technique in detecting voltage instability during transient behavior of the system, is illustrated in this work. The work is progressed through three main stages. First stage is simulating power system using PSAF. Second stage is handling and processing data, before using it by the AIS technique. Third stage is using the developed AIS technique to detect system stability, and inform System Protection Center (SPC) in case of voltage instability.

The newly AIS based voltage instability detection approach is tested on the IEEE 14-bus system. It shows good results in expecting system behavior. PSAF program was tested by applying different windows (where each 6 windows are equivalent to 0.1 seconds). Prediction process using 6 windows succeeds in predicting stability mode. The developed technique succeeds in predicting the behavior of the system in micro seconds which leads it to be applicable in real time applications.

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