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ENHANCEMENT OF PSS AND REDUCTION IN POWER LOSSES USING TCSC AND SVC FOR THREE AREA INTERCONNECTED POWER SYSTEM

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ABSTRACT

The aim of the paper is to enhance the power system stability and to reduce the power losses in three area interconnected power system [10] using TCSC and SVC. In present power system, controllability of power losses is a major issue, and also enhancement of system stability is an important task to improve power system .For that purpose we are analyzing 47 bus system i.e. interconnection of three areas, such as 9 bus , 14 bus and 24 bus. The comparison between general 47 bus system is detailed and proposed new HVDC system for interconnection in 47 bus system using FACTS device is also detailed. The best location of the FACTS device is recognized by Power Flow Analysis .The analysis is carried out using power system Analysis Toolbox (PSAT) software.In this paper we are going to find the best location of installing facts devices in 47 bus system. We are analyzing the system behavior and minimization of real power losses in the 47-bus system and advance technology of facts device enhances stability. we are using TCSC and SVC within the system and identify the best location where the real power losses are reduced compared with 47-bus system without facts devices, and we are placing HVDC links to interconnect the three areas such as 9-bus, 14-bus & 24-bus to form 47-bus system .While comparing individual TCSC device, SVC device, HVDC link and every possible combination (TCSC, SVC & HVDC), the real power losses are minimized (less) in combination when compare to individual cases. Combination of both devices gives better performance for 47 bus system. The simulation has been carried out in PSAT [9] interfaced with MATLAB package.

Index Terms: *Interconnections, HVDC, TCSC, SVC and Eigen values etc.*

1. INTRODUCTION

Every transmission network has its own maximum loading capacity because of well-known thermal limits of the material used in the construction of power system network. Angle stability is defined by the load angle (phasor difference between sending end and receiving end voltages). While the voltage stability is defined by the magnitude of receiving end voltage phasor by keeping sending end voltage fixed. So receiving end voltage of the transmission line solely depends upon variations (rise or drop) in the reactance of the line. When system voltage is low, one has to generate reactive power (capacitive). When system voltage is high, one must absorb reactive power (inductive) [5].therefore reactive power plays the major role to improve the power transfer capability of the system.

The reactive power requirement can be met by the generator itself, but it has its own limits (capability).The alternative s we have is either to take apart alternator reserved as a reactive power generator or produce the reactive power exterior to the central generator. This purpose can be served by linking the capacitor banks or inductive reactors in series, parallel or both as per our necessity, by using which the reactive power generated and manipulated as per our requirement.

There are different types of power electronics devices called FACTS controllers named as TCSC, SVC, and STATCOM etc. which enhances the real and reactive power flows in the transmission network. It is well known that shunt and series compensation can be used to increase the maximum transfer capabilities of power networks. With the improvements in current and voltage handling capabilities of power electronic devices that have allowed for the development of Flexible AC Transmission Systems (FACTS), the possibility has arisen of using different types of controllers for efficient shunt and series compensation. Thus, FACTS controllers [12] based on Thyristor controlled reactors (TCRs), such as Static VAR Compensators (SVCs) [4] and Thyristor Controlled Series Capacitors (TCSCs), are being used by several utilities to compensate their systems.

More recently, various types of controllers for shunt and series compensation, based on voltage source inverters (VSIs), i.e., shunt and Series Static Synchronous Compensators (STATCOMs and SSSCs) and Unified Power Flow Controllers (UPFCs) have been proposed and developed. This paper concentrates on thoroughly studying the effects of SVCs and TCSCs on interconnected power system. While improving the reactive power flow, FACTS controllers' simultaneously controls the power system operation effectively. The reactive power flows and active power flows, voltage phasors, currents, transient stability, even power oscillation damping's can also be effective modified by using FACTS controllers

This paper organized in six sections. First section gives brief introduction to this paper while second section explains about interconnections and its advantages, Section three and four explains about FACTS controllers that we used in this paper to carry out simulations. Section five consists of case studies and simulations results and various tabulations are provided. Finally conclusions are made in sixth section.

2. POWER SYSTEM INTERCONNECTIONS

The demand for electrical energy in industrialized countries keeps on growing, whereas in emerging countries it increases very fast. Deregulation and privatization as well as ecological constraints became a new challenge for electric power supply. National and regional power systems are gradually being interconnected to very large and complex systems, covering whole continents. The goal is to provide sustainable delivery of the most economical and also environmentally- compatible energy. [1] The inter-connection should further improve the security of power supply, which became an important an important factor in the economy.

The HVDC technology [6] offers a number of technical and economical advantages for inter-connection. Adjustments in the AC systems are not needed. HVDC provides therefore often an overall more economical solution. On long term, however, a hybrid interconnection could be the favorable solution, starting with an HVDC interconnection utilizing its advantages [2], and later be extended by an additional AC inter-connection. In principle, a hybrid AC/DC solution does not have any limitation for the size of the interconnected networks.

The systems interconnection enabled the use of these large units without the risk for operation. In case of outages, the surrounding systems can deliver the lacking power until the own reserve generation is activated. Another important advantage of the interconnection is the use of the most favorable energy resources, based on the contractual agreement between the partners in the interconnected system. The flexibility of constructing power plants in the favorable locations and the increase in total reliability of the interconnected system are further advantages.

2.1 ADVANTAGES OF INTERCONNECTION

- ✓ Possibility to use larger units and more economical Power Plants present in the system.
- ✓ Reduction in the necessary Reserve Capacity of the System
- ✓ Utilization of most favorable Energy Resources
- ✓ Flexibility of building new Power Plants at favorable Locations
- ✓ Increase in Reliability of the Systems
- ✓ Reduction in Losses by an optimized System Operation

3. THYRISTOR CONTROLLED SERIES COMPENSATOR

TCSC is a typical series FACTS device comprising a thyristor controlled reactor across a series capacitor, which is used to differ the reactance of the transmission line. It reduces the electrical distance of the compensated transmission line. The TCSC may be lone, big unit, or might consist of numerous equally or different-sized minor capacitors in turn to attain an advanced performance. Figure 3.1 shows the layout of one phase of TCSC. Since TCSC works through the transmission system directly, it is much more effectual than the shunt FACTS strategy in the use of power flow run and power system fluctuation damping control (de Souza et al 1997; Lof et al 1992).

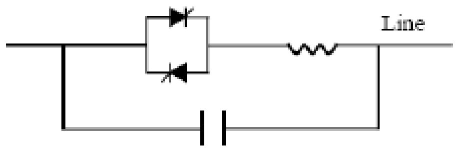

Figure3.1: Thyristor Controlled Series Compensator model

4. STATIC VAR COMPENSATOR

The static VAR compensator (SVC) [4] generates or absorbs shunt reactive power at its point of connections.SVC are also used primarily in power systems for voltage control as either an end in itself or a means of achieving other objectives, such as system stabilization. SVC is a general term for a thyristor-controlled or thyristor-switched reactor, and/or thyristor-switched capacitor or combination. SVC is based on thyristors without the gate turn-off capability. It includes separate equipment for leading and lagging VARs; the thyristor-controlled or thyristor-switched reactor for absorbing reactive power and thyristor-switched capacitor for supplying the reactive power.

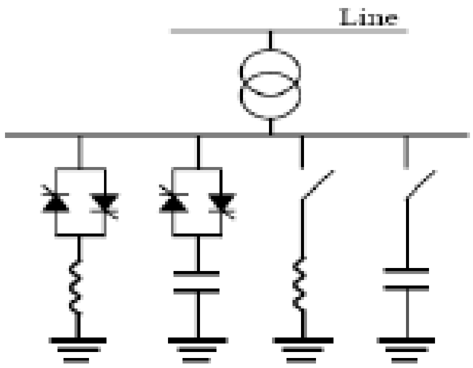

Figure4.1: Static VAR Compensator (SVC).

SVC is a general phrase for a thyristor-controlled or thyristor switch reactor, and/or thyristor-switched capacitor or combination as shown in figure 4.5. From functioning point of view, the SVC behaves similar to shuntly-attached variable reactance, which either produces or absorbs reactive power in turn to control the voltage magnitude at the point of link to the AC network. So it is extensively used for fast reactive power and voltage regulation support. In power flow analysis, the total susceptance of the SVC may be taken as variable

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and additional voltage or reactive power control equation should be included. The firing angle control of the thyristor enables the Static VAR Compensator, to cover almost instant speed of response; based on the operation of SVC it can be configured as variable shunt susceptance model and firing-angle representation.

5. CASE STUDY

Three area interconnected 47- bus system has been investigated in below shown figure (IEEE 9 BUS + IEEE 14 BUS + IEEE 24 BUS)

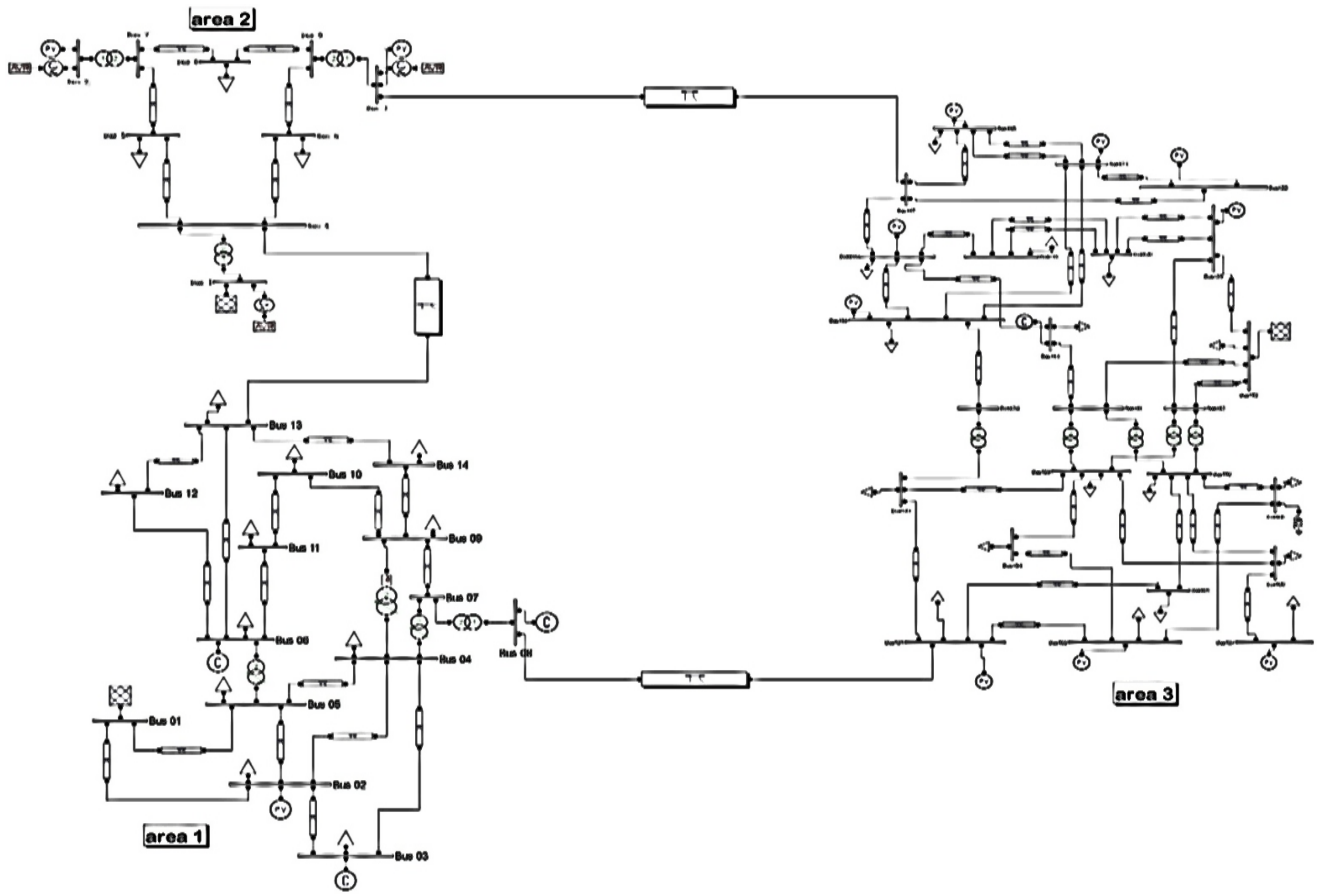

Figure 5.1: layout of three area interconnected system using normal transmission lines(π-model)

In this case, three areas (IEEE 9 bus + IEEE 14 bus + IEEE 24bus) are interconnected using normal transmission line (π-model). While doing so, more machines are available to the loads, and reserve capacity of the machines can also be reduces as the loads in one area are shared by the other areas. We can also improve the reliability of the system. So by using interconnections we can deliver power to the load economically. Total losses are also shared by the total system (all areas), burden on existing systems can be reduced. Figure 5.1 shows the layout of three area interconnected system.

5.1 SIMULATION RESULTS

5.1.1. Power Flow Analysis

The power flow analysis is done over the three area interconnection system. The total analysis can be explained using five cases. One can view the clear betterment in stability and reduction in losses while using FACTS controllers rather than the without FACTS devices by going through the tabulations provided. The following are the five cases which we studied over this paper

Case1: Three area interconnected system using normal transmission line.

Case2: Three area interconnected system using HVDC links.

Case3: Three area interconnected system using HVDC links and placing TCSC at optimal locations of each area and all areas.

Case4: Three area interconnected system using HVDC links and placing SVC at optimal location in area 3.

Case5: Three area interconnected system using HVDC links and TCSC in all three areas and SVC at optimal location in area 3.

Figure 5.1 presents the bus system for the case one. Whereas the Figure 5.2 presents the bus system for case five. Remaining cases can be understand by going through this two cases.

Table 5.1: Tabulation to compare losses in the system with possible interconnections and SVC placement

Device Details	TOTAL GENERATION (p.u.)		TOTAL LOAD (p.u.)		TOTAL REAL POWER LOSSES (p.u.)
	REAL	REACTIVE	REAL	REACTIVE	
Interconnection using normal transmission line	36.1798	9.411	35.276	9.9944	0.90375
Interconnection using HVDC links	36.1298	9.6856	35.276	9.9941	0.85378
SVC at optimal location in area 3	36.1268	9.7007	35.276	9.9941	0.85079

Table 5.2: Tabulation to compare performance of TCSC at various locations

Device Details	TOTAL GENERATION (p.u.)		TOTAL LOAD (p.u.)		TOTAL REAL POWER LOSSES (p.u.)
	REAL	REACTIVE	REAL	REACTIVE	
TCSC at optimal locations in area 1	36.1296	9.7187	35.276	9.9941	0.85036
TCSC at optimal location in area 2	36.1279	9.7335	35.276	9.9941	0.85189
TCSC at optimal location in area 3	36.1279	9.7335	35.276	9.9941	0.85189
TCSC at optimal location in all areas	36.1279	9.7335	35.276	9.9941	0.85189

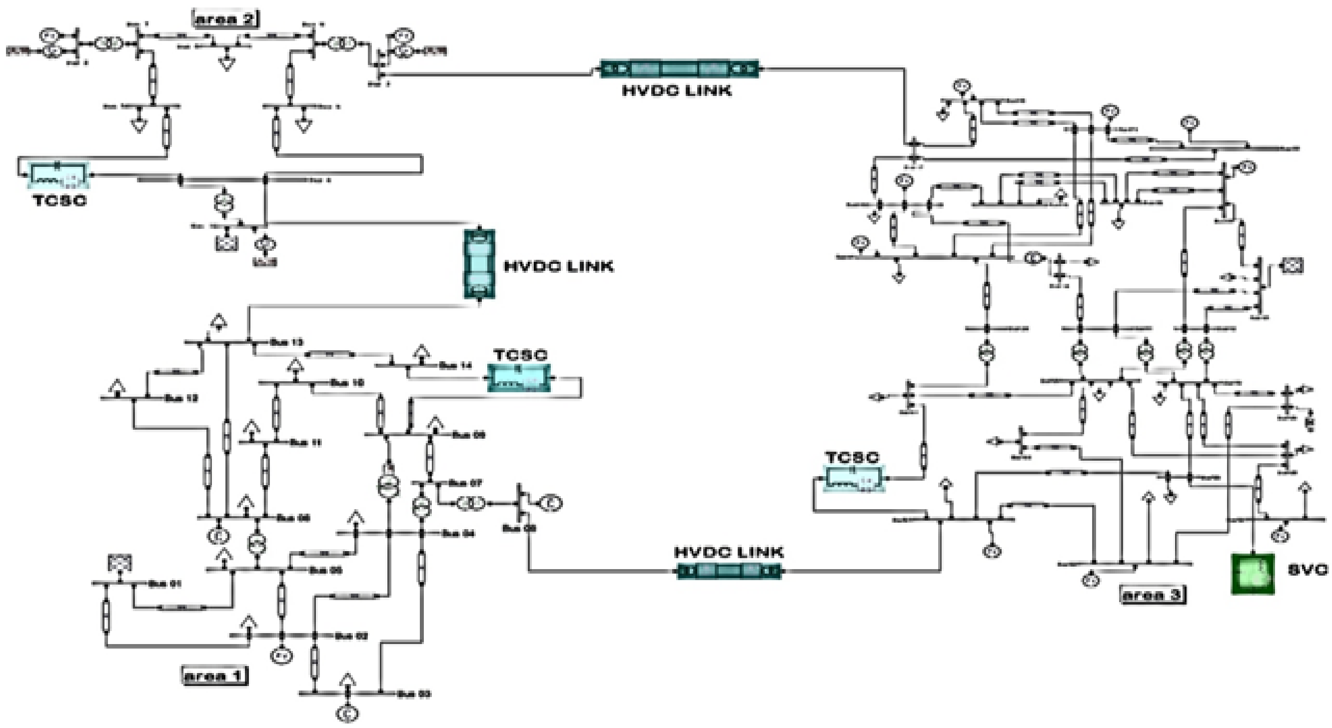

Figure 5.2: layout of three area interconnected system using HVDC links and TCSC at optimal locations in all areas and SVC at optimal location in area 3

Figure 5.2 represents all FACTS controllers at their optimal locations in all areas.

Table 5.3: Tabulation to compare losses using TCSC at various percentage of compensation and placed at optimal location of all areas and SVC at optimal location in area 3

Device Details	TOTAL GENERATION (p.u.)		TOTAL LOAD (p.u.)		TOTAL REAL POWER LOSSES (p.u.)
	REAL	REACTIVE	REAL	REACTIVE	
TCSC at all areas with 10% compensation and SVC at optimal in area 3	36.1128	9.8201	35.276	9.9949	0.83683
TCSC at all areas with 30% compensation and SVC at optimal in area 3	36.0507	9.9189	35.276	9.9954	0.77473
TCSC at all areas with 50% compensation and SVC at optimal in area 3	35.9579	10.0313	35.276	9.9989	0.68190

5.1.2. EIGEN VALUE ANALYSIS

Eigen value analysis of the system is used to determine the stability of the system, here in this paper, by using TCSC and SVC at the optimal locations in the three area interconnected system as shown in Fig: 5.1 and 5.2, we can shift the Eigen values from positive real axis to negative real axis, which means improvement of system stability [11]. The following Plots which are generated using PSAT are used to understand the stability of the interconnected system with case one and case five. PSAT calculates impedance of every bus present in the system. These impedances are used to generate the transfer function of the system which in turn used to plot root locus of the system, which defines dynamic stability. As we all know in power system stability by Eigen value analysis can be determined by number of Eigen's present in negative real axis. As more number of Eigen's shifted to negative real axis, the system becomes more stable. By using various devices placed at optimal location in all areas we can improve the stability of the system. Eigen value plots for case one and case five are presented below.

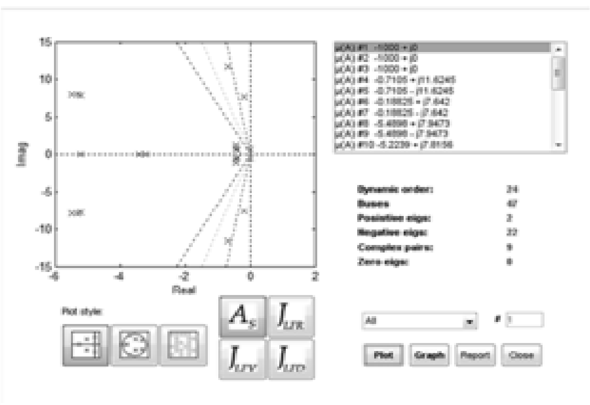

Figure 5.3: Eigen value plot for case 1

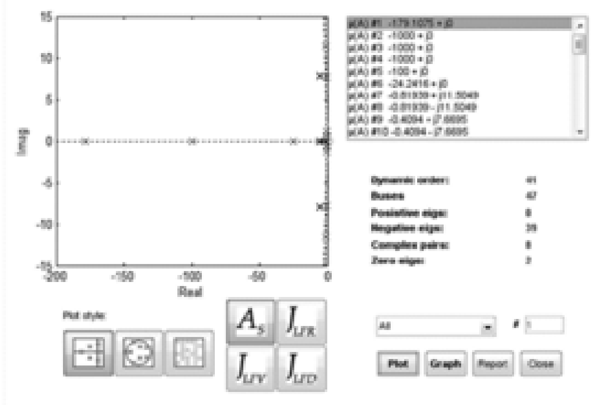

Figure 5.4: Eigen value plot for case 5 (TCSC at 50% compensation)

We can understand the improvement of dynamic order and power system stability by going through the tabulations provide below.

By going through these tables we come to know that, we can achieve enhanced stability and we can reduce power losses by using TCSC, SVC and HVDC links

Table 5.4: Tabulation to compare Eigen values of possible interconnections and SVC

Statistics	Normal interconnection	Interconnection using HVDC	SVC placed at optimal location in area 3
Dynamic Order	24	33	35
Negative Eigen	22	31	33
Positive Eigen	2	0	0
Complex Pair	9	8	8
Zero Eigen	0	2	2

Table 5.5: Tabulation to compare Eigen values of TCSC at various locations

Statistics	TCSC at optimal location in area 1	TCSC at optimal location in area 2	TCSC at optimal location in area 3	TCSC at optimal locations in all areas
Dynamic Order	35	35	35	39
Negative Eigen	33	32	32	35
Positive Eigen	0	0	0	0
Complex Pair	8	8	8	8
Zero Eigen	2	3	3	4

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Table 5.6: Tabulation to compare Eigen values of TCSC at various percentage of compensation and placed at optimal location of all areas and SVC at optimal location in area 3

Statistics	TCSC at optimal location in all areas (10% compensation)and SVC at optimal location in area 3	TCSC at optimal location in all areas (30% compensation)and SVC at optimal location in area 3	TCSC at optimal location in all areas (50% compensation)and SVC at optimal location in area 3
Dynamic Order	41	41	41
Negative Eigen	37	36	39
Positive Eigen	0	0	0
Complex Pair	8	8	8
Zero Eigen	4	5	2

6. CONCLUSION

In this project PSAT interfaced with MATLAB is used to carried out simulations of three area interconnected system (9 bus system,14 bus system, 24 bus system), we. We can observe that by placing TCSC at optimal places at all areas, one can reduce total real power losses and can shift positive Eigen's to negative real axis, Hence stability of the system improves considerably. We can go through the tabulations for better perception.

We can use SVC at optimal location in area 3 to get better results than all other possibilities considering various economic reasons. SVC provides better stability comparing with TCSC. By choosing these two devices effectively and placing them at correct positions one can improve the stability of the system economically. Finally we operate TCSC at various compensation levels along with SVC at area 3, So that we can conclude that by increasing percentage level of compensation of TCSC, losses can be reduced, stability improved. As we all know, by reducing losses we can meet loads effectively. This project also explains about interconnection of three areas. We can also conclude that interconnections using HVDC links can reduce the overall system losses and also improves the dynamic order of the system.

In this paper simulations are carried out using PSAT interfacing with MATLAB. This project concentrates on TCSC and SVC only. In future this project can be carried out using various other FACTS controllers for betterment. We can also carry out this project by using Fuzzy controllers. In future artificial intelligence plays a major role in the world as it is much nearer to the human intelligence. So we can also carry out these simulations using ANN methods.

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