Impact of Passive Cell (PC) and Active Distributive Network Cell (ADNC) on Power System Oscillation

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ABSTRACT
Impact of Active Distribution Network Cell (ADNC) Study on Power System Oscillation requires modelling of power system components. The system covers the well knows Two Areas-System benchmark which studies low frequency electro-mechanical oscillations in large interconnected power system. This study examined the effect of passive cell on Active Distributive Network Cell (ADNC). The method adopted was modelled using Power System Analysis Toolbox in MATLAB environment. The result was varied by analysizing the effect of passive cell at different position and Active Distributive Network Cell (ADNC) at different positions. The damping effect is also analyse through reactive and real (active) power profile.

CCS Concepts
• General and reference →Cross-computing tools and techniques →Experimentation

Keywords
ADNC, Passive Cell, PSS

1. INTRODUCTION
The types of load in modern power systems range "from simple resistive load to more complicated loads with electronic controllers" [1-14]. Power system complexity and their characteristic nonlinearity increase with increase in controllers and loads. This in turn makes power systems to exhibit increasing instability problem. Power instability problems can cause partial or total blackout. This problems can be categorized into "voltage, phase angle and frequency related problems" [1-7].

In order to address power systems disturbances many devices have been invented and a number of solutions have been proffered to enhance the effectiveness of these devices. These include fast exciter or Automatic Voltage Regulators (AVR), Power System Stabilizer (PSS) which helps to produce the fine adjustment needed to damp out electromechanical or low frequency oscillations in power systems [1, 7-10]. Existing study [1] examined the "Impact of Active Distribution Network Cell (ADNC) on Power System Oscillation." The objective of the work is to examined the impact of Passive Cell (PC) on Active Distribution Network Cell (ADNC) and to analyze the small and large signal stability changes and to analyze the power flow signal [1,7].

2. METHODOLOGY
Impact of Active Distribution Network Cell Study on Power System Oscillation requires modelling of power system components. The system covers the well knows Two Areas-System benchmark. The benchmark is a model was created by Canadian Association to presents the various types of oscillations that may happen in large/small power systems. It is also known as Kunder's system which "is specifically designed to study low frequency electromechanical oscillations in large interconnected power systems" [1].

2.1 System Model
The 2-Area System was modelled using Power System Analysis Toolbox (PSAT) embedded in Matlab Environment. Figure 1 shows the design overview. The analysis of the system model is summarized below:

i.) The System consists of two areas: Area I region is indicated by the buses on the left half side of Figure 1 and Area II region is indicated by the buses on the right half.

ii.) The two areas are connected together by a transmission line of power, voltage rating and frequency of 100MVA, 20kV and 60Hz respectively.

iii.) The system generally consists of 4 PSSs, 4 AVRs, 5 Synchronous Generators, 3 PV Generators, 3 ZIP Loads, 3 PQ Constants, 11 Buses, 5 Transformers, 5 transmission lines, 1 Slack Bus, and 1 Induction Machine.

iv.) Each of the Area consists of 2 Synchronous Generators, each of rating 900MVA of Power and 20kV of Voltage.

v.) Each generator is equipped with AVR and PSS.

vi.) The loads are applied at Bus 6 and Bus 5.

vii.) The Slack Bus, PSS, AVR, Synchronous Generator, Transformers, and Transmission Lines are all linked together by Buses of rating 20kV.

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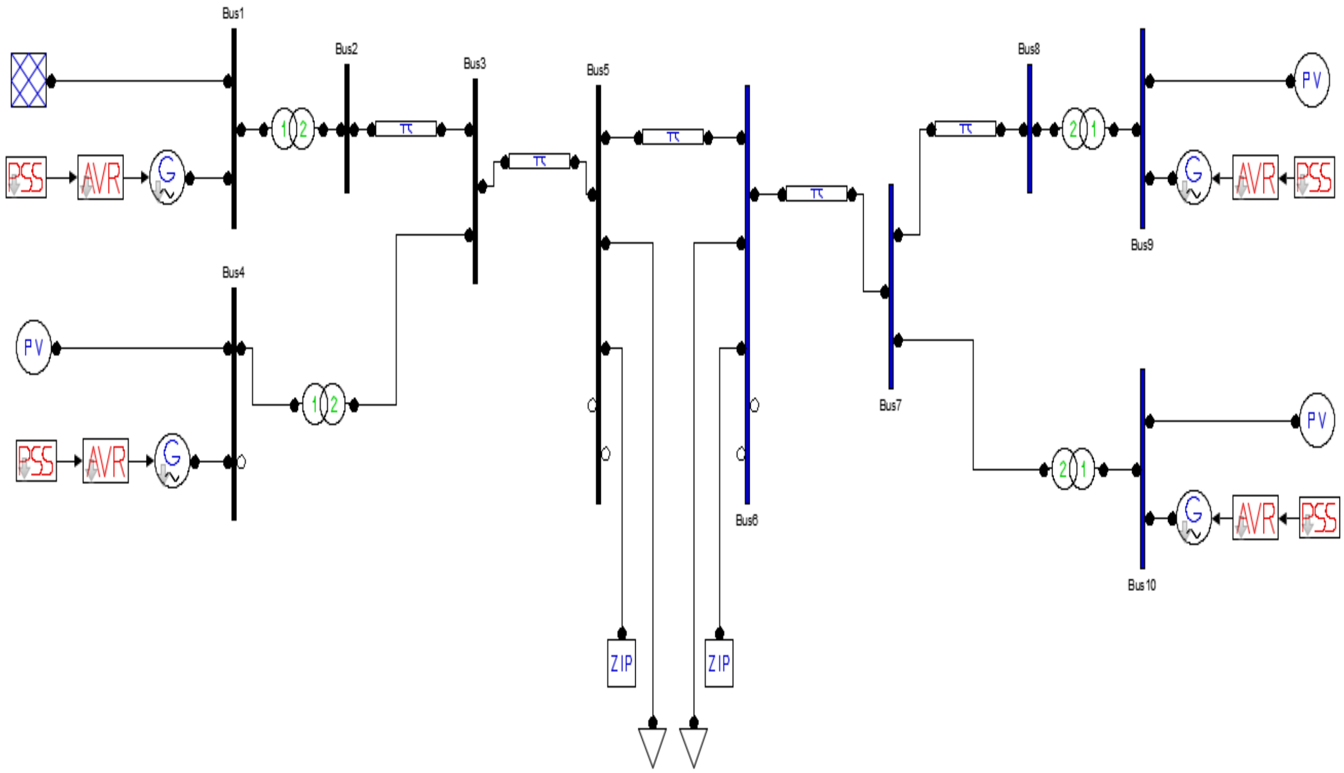

Figure 1: The Two Area System (PSAT Implementation)

2.2 Design Approach

There are three cases considered in the system design, namely: Base Case, in which the system is considered neutrally as depicted in Figure 1; Passive Cell (PC) Case and Active Distributive Network Cell (ADNC) which are varied at Bus 5 and Bus 6 as shown in Figure 2 (a) and 2 (b) respectively.

The system with passive network cell consists of Induction Machine, constant PQ load and ZIP load.

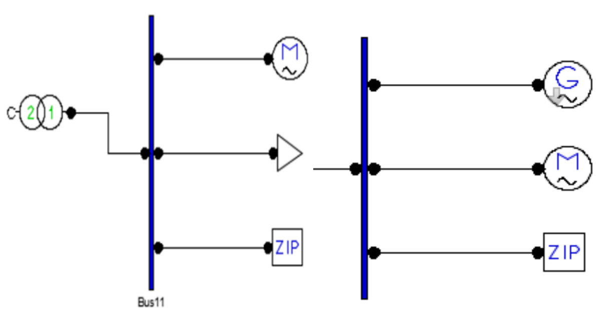

Figure 2: (a)Passive Cell *Figure 2:(b) ADNC*

The Active Distributive Network Cell consists of the following: ZIP Load, Back-to-Back Converter, Synchronous Generator and Inductor Motor [1].

3. IMPLEMENTATION AND RESULTS

3.1 Base Case Analysis

The base case load benchmark is P= 2734 MW, with 100 MW transferred from Area I to Area II over the tie-line. Results in Figures 3 and 4 show the power flow and the eigenvalues for the base case system.

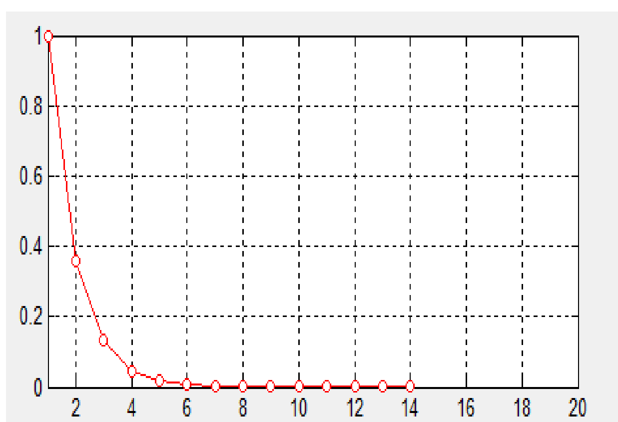

Figure 3: Power flow curve

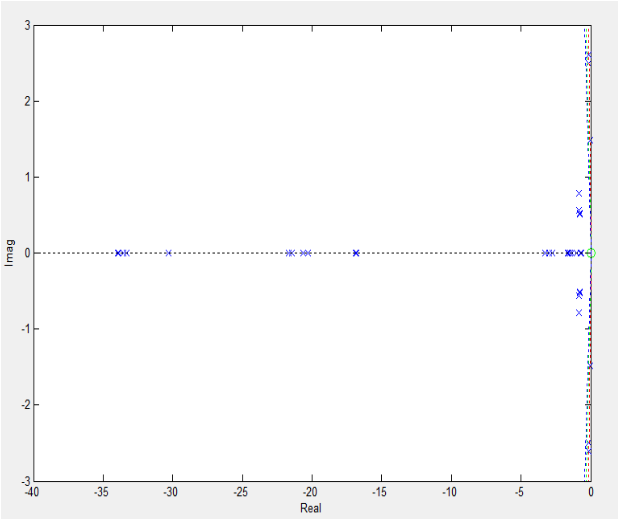

Figure 4: Eigenvalues diagram of Two Area System (Base Case)

3.2 System with Passive Cell (Loads and IM)

In order to study and analyze the impact of Passive Cell in the Power System Oscillation, Passive Cells which consists of Loads (ZIP and PQ) and Induction Machine are applied to the system (Figure 5).

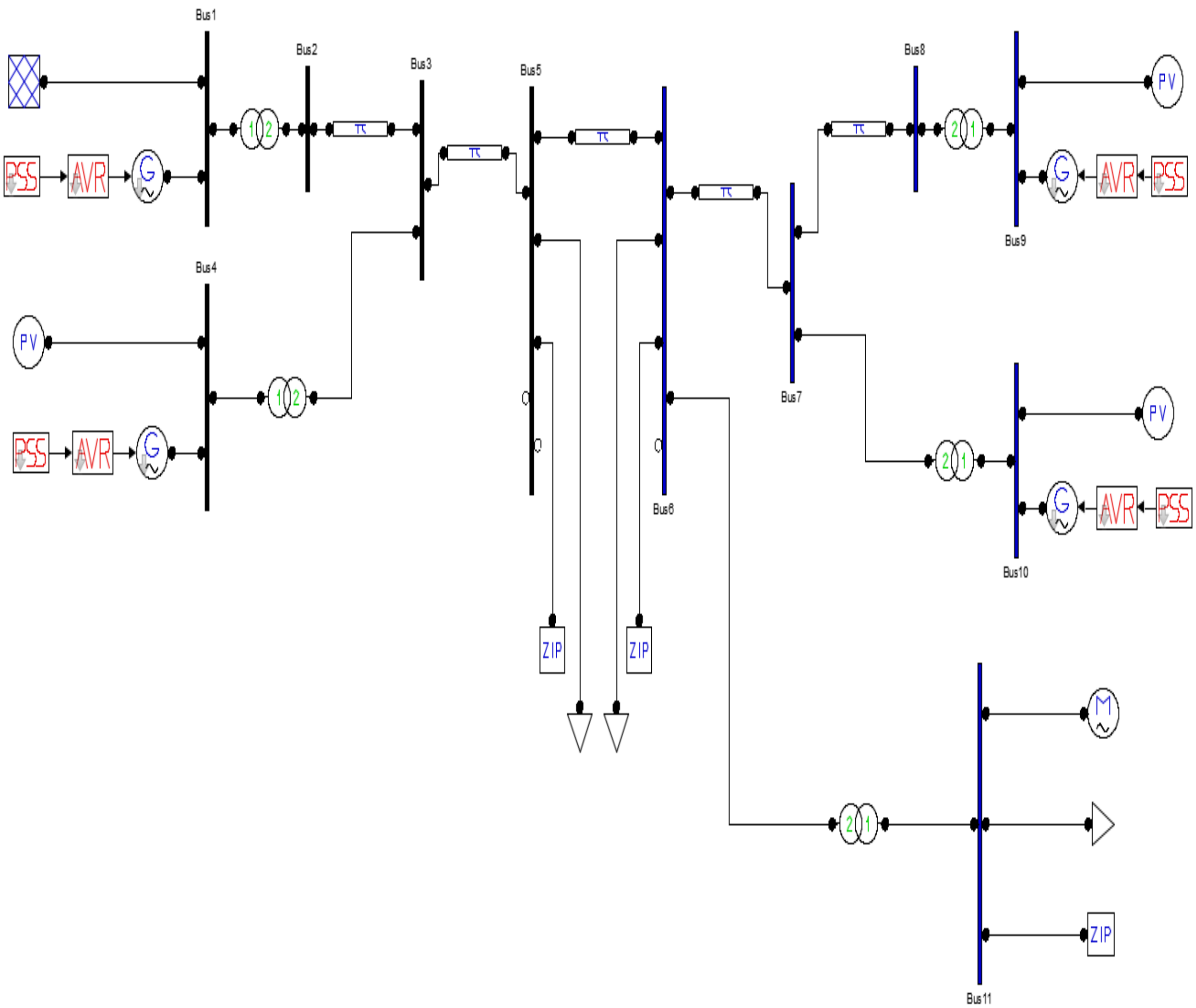

Figure 5: PSAT Implementation of the Study with Passive Cell

The power flow of system with PC at bus 6, Area II is as shown in Figure 6. Figure 7 is the eigenvalues curve for the system with PC.

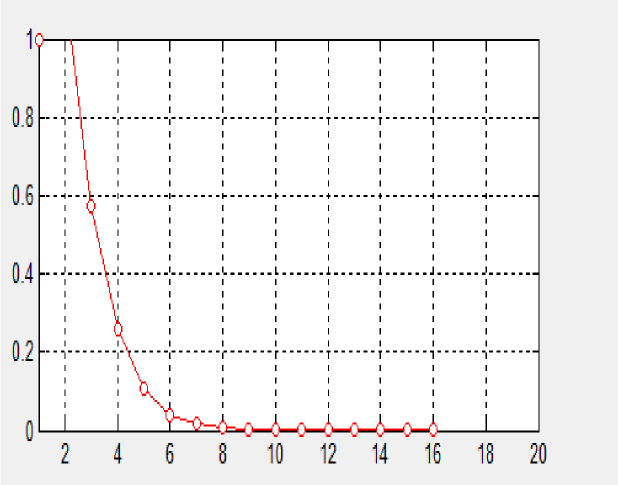

Figure 6: Power Flow by the System with PC (Area II)

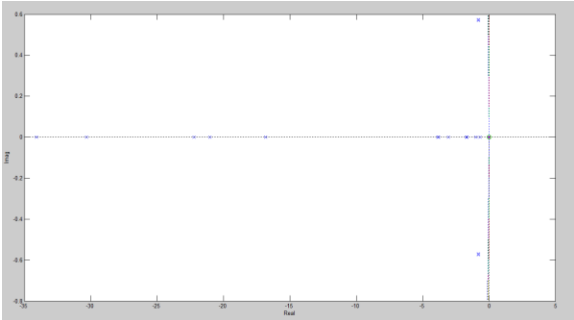

Figure 7: Eigenvalues report at Area II for system with PC

Figure 8 shows the power flow analysis of the system with PC implementation at Area I while Figure 9 is the eigenvalue for the same system.

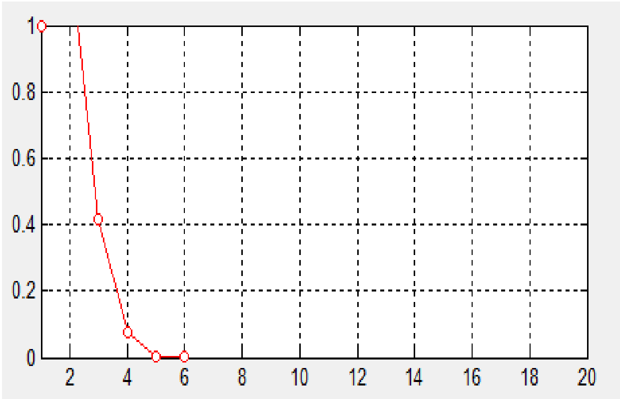

Figure 8: Power flow analysis of the passive cell at Area I

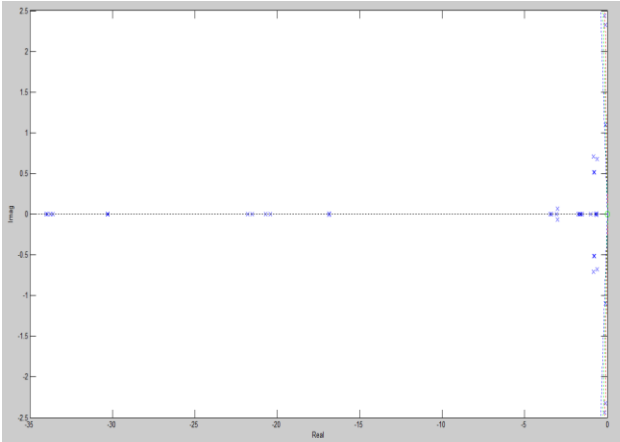

Figure 9: Eigenvalue report of passive cell at Area I

3.3 IMPLEMENTATION OF ADNC

Figure 10 represents the implementation of the two Area System of the study by replacing the Induction Machine as shown in Figure 5 with Synchronous Machine. The ADNC consists of Synchronous Machine, ZIP load and constant PQ load.

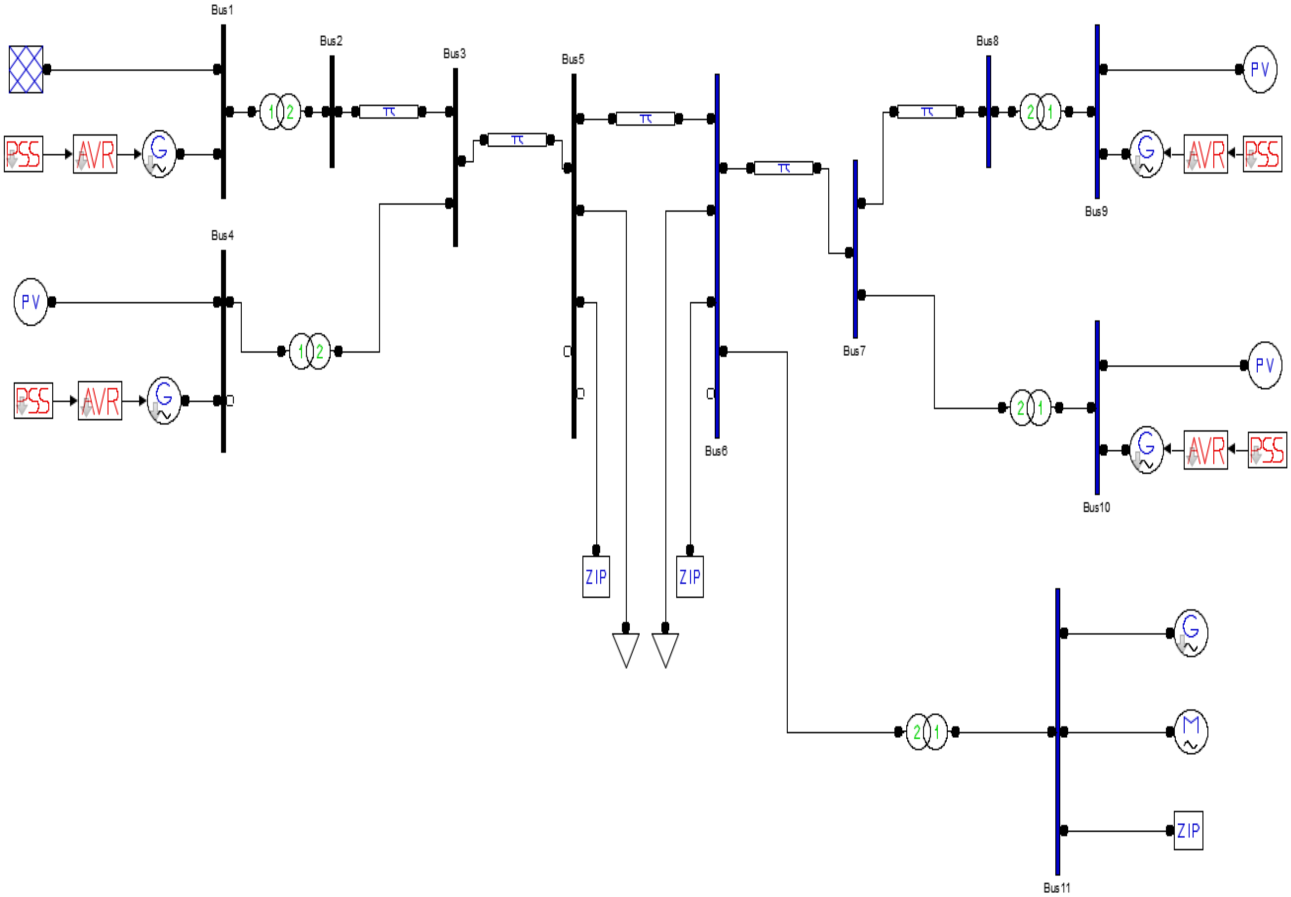

Figure 10: Power System with ADNC (PSAT Implementation)

Figure 11 is the power flow analysis of the implementation with ADNC at Area II and Figure 12 is the eigenvalue.

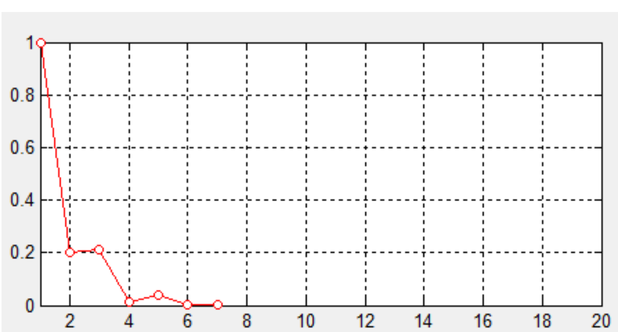

Figure 11: Power flow of ADNC system at Area II

It can be seen from Figure 11 that power flow maximum convergency error at bus 6 is the same as that for PC at Bus 6 (Figure 8).

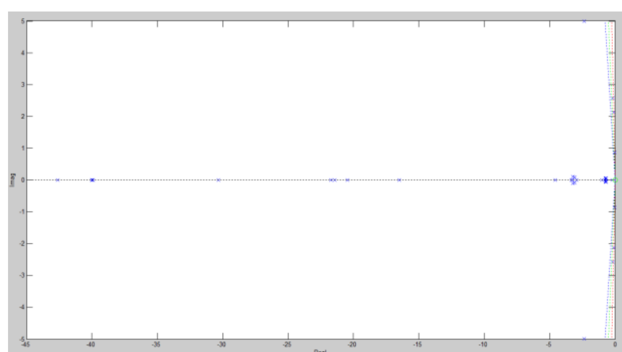

Figure 12: Eigen value report of ADNC at Area II

For implementation of the ADNC system at Area I, the power flow analysis is shown in Figure 13 and the eigenvalue graph is shown in Figure 14

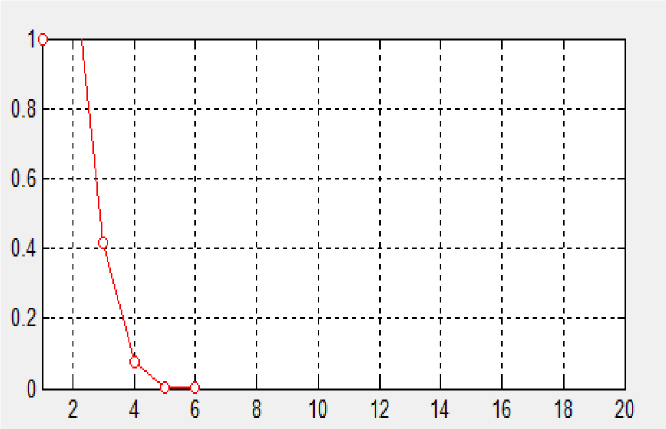

Figure 13: Power flow in ADNC at Area I

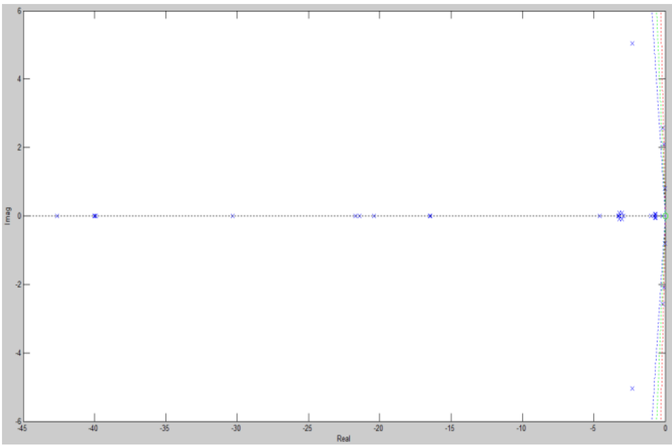

Figure 14: Eigenvalue report at Area I

4. DISCUSSION

Table 1 shows the report of the Total Generation, Total Load and Total Losses of both Real and Reactive Power of the model for each of the cases i.e. base case, PC case and ADNC case. From the table, it can be seen that ADNC has a great impact on power system oscillation than any of the other in term of the total generation, total losses and total load of the model.

Table 1: Global Summary Report

		Total Generation		Total Load		Total Losses	
		Real Power (p.u)	Reactive Power (p.u)	Real Power (p.u)	Reactive Power (p.u)	Real Power (p.u)	Reactive Power (p.u)
Base Case		1.6855	2.2426	1.6	1.2	0.08552	1.0426
Passive Cell	Area I	-0.69431	-1.8858	-2.5538	-28.2091	1.8595	26.3233
	Area II	1.2993	5.8656	0.92267	0.69068	0.37666	5.175
ADNC	Area I	1.4161	19.0168	75.4378	-79.5421	-79.0218	98.5599
	Area II	107.4515	1185.7181	-0.71926	3.1978	108.1707	1182.5203

4.1 Comparison between existing model and new model

In term of the design model, when solving the power flow from the existing design, there are errors generated, shown as follows:

Definition of system connections ...

Error: Block <Line3> cannot be connected to block <Line4>.

Error: Block <Line4> cannot be connected to block <Line3>.

Error: Block <Line5> cannot be connected to block <Line6>.

Error: Block <Line6> cannot be connected to block <Line5>.

* * *

Failed conversion from Simulink model: Simulink model is not well-formed (check links).

Attempted to access idx(2); index out of bounds because numel(idx)=1.

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These errors make the existing model heavily error-prone. The errors are corrected using the new model by removing the transmission lines (compare Figure 15 with Figure 16).

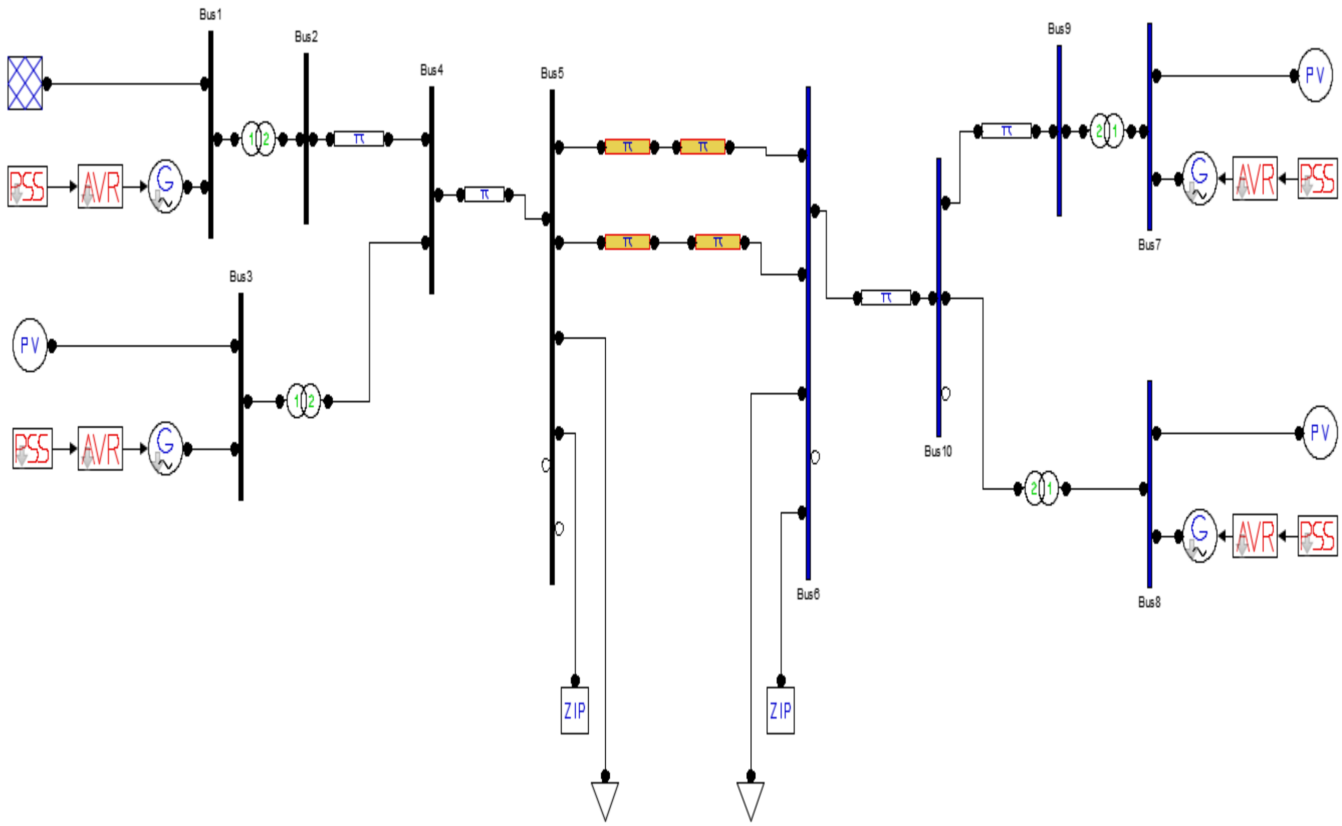

Figure 15: Existing model

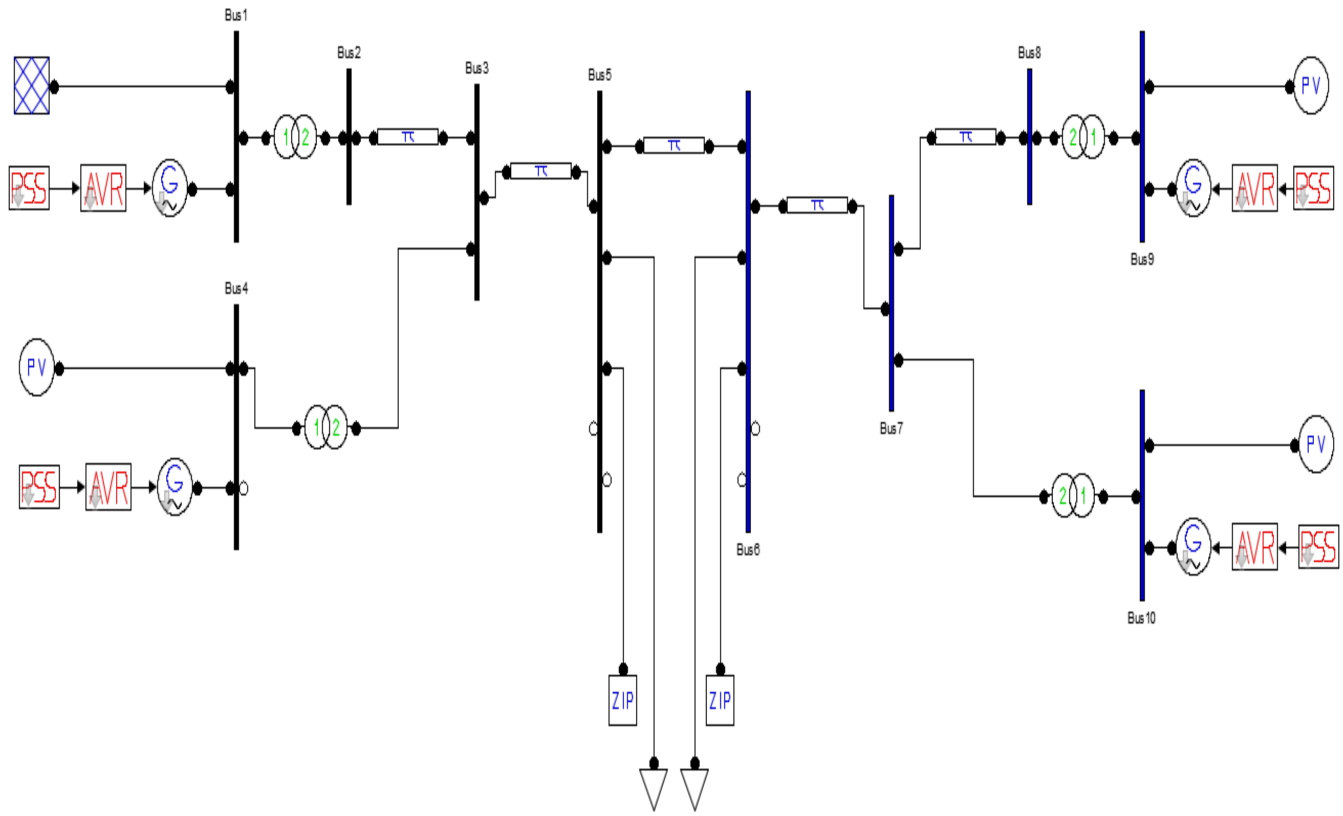

Figure 16: New Model

Since the existing model is invalidated, some of the responses of the analysis analyzed are not gotten when using the new model. New dimensions were then taken to analyze the impact of both passive cell and active distribution network cell on power system oscillation.

In term of the continuous and time domain analysis, only the base case has continuous and time domain flow. The passive cell and ADNC (both Area I and Area II) do not have continuous state variable.

5. CONCLUSION

As shown by the simulation of the base case, where there is no additional elements connected to the two area system, it has been found that all the PSS types exhibit damping effect under small disturbances.

Then, in the subsequent simulation model, adding a regular load and induction motor as a passive cell, in different locations, and their impact on the system loading have been analyzed. The results revealed that the system becomes instable when the passive cell is connected at the midpoint of tie line. Thus, small signal analysis using PSAT where conducted to find the reason of the instability.

Small signal analysis revealed that one of the induction motor eigenvalues has a positive real part when the passive cell is installed at the mid-point which is the cause for system instability. Then, the impact of the active distribution network cell (ADNC) on the power system oscillation was been investigated. Increasing in the loading level is actually reflected as an additional stress on the tie-line that may cause system instability. Results show that ADNC has a great impact on power system oscillation than any of the other models in term of the total generation, total losses and total load of the model. The power flow signals also show that there is a great impact by passive cell and ADNC on power system oscillation.

6. REFERENCES

[1] Alawasa, H. O. 2013. Impact of Active Distribution Network Cell (ADNC) on Power System Oscillation.

[2] Ghandhari, M. 2000. Control Lyapunov functions: A control strategy for damping of power oscillations in large power systems.

[3] He, J., & Malik, O. 1997. An adaptive power system stabilizer based on recurrent neural networks. *Energy Conversion, IEEE Transactions on*, *12*(4), 413–418.

[4] Hemmingsson, M. 2003. Power system oscillations-detection, estimation and control, Lund University.

[5] Hsu, Y.-Y., & Chen, C.-R. 1991. Tuning of power system stabilizers using an artificial neural network. *Energy Conversion, IEEE Transactions on*, *6*(4), 1991, 612–619.

[6] K. Prasertwong,, N. Mithulananthan, & D. Thakur. (n.d.). *Understanding low frequency oscillation in power systems*. Power and Energy System Group, School of Information Technology and Electrical Engineering, The University of Queensland, St. Lucia Campus, Brisbane, Qld 4072, Australia: Electric Power System Management, Energy Field of Study, Asian Institute of Technology, Klongluang, P.O. Box 4, Pathumthani, Thailand. Retrieved from mithulan@itee.uq.edu.au

[7] Kauhaniemi, K., & Kumpulainen, L. 2004. Impact of distributed generation on the protection of distribution networks.

[8] Kundur, P., Balu, N. J., & Lauby, M. G. 1994. *Power system stability and control* (Vol. 7). McGraw-hill New York.

[9] Lauri, K., Hannu, L., & Risto, K. (n.d.). *Distribution Network 2030, Vision of the Future Power System*.

[10] Lopes, J., Hatziargyriou, N., Mutale, J., Djapic, P., & Jenkins, N. 2007. Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities. *Electric Power Systems Research*, *77*(9), 1189–1203.

[11] Mithulananthan, N., Canizares, C. A., Reeve, J., & Rogers, G. J. 2003. Comparison of PSS, SVC, and STATCOM controllers for damping power system oscillations. *Power Systems, IEEE Transactions on*, *18*(2), 786–792.

[12] Pal, B., & Chaudhuri, B. 2005. *Robust Control in Power Systems* (Vol. XXVI).

[13] Segal, R., Sharma, A., & Kothari, M. 2004. A self-tuning power system stabilizer based on artificial neural network. *International journal of electrical power & energy systems*, *26*(6), 423–430.

[14] Wang, X.-F., Song, Y.-H., Irving, M., Song, Y.-H., & Song, Y.-H. 2008. *Modern power systems analysis*. Springer.