International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 4 Issue 11, November - 2020, Pages: 60-69

Assessment of PSS Performance for Damping Low Frequency Oscillations in Power System

Bahaaldeen Mohammed 1, Badreldeen Abdallah2, Mohammed Elmubarak Adam 3 , Abubakr Mustafa 4 , Osman Osman 5, Azzam Abdlmoneam6, Mohammed Mohammed 7

[1]Department of Electrical Engineering, Alzaiem Alazhari University, Khartoum, Sudan
bahaaldeen.ahmedaltegani@yahoo.com

[2]Department of Electrical Engineering, Sudan University of Science and Technology, Khartoum, Sudan
bdryounos111@gmail.com

[3]Department of Electrical and Electronics Engineering, University of Bahri, Khartoum, Sudan
mohammedelmubarak@yahoo.com

[4]Department of Electrical Engineering, Sudan University of Science and Technology, Khartoum, Sudan
abubakrmahjoub10@gmail.com

[5]Department of Electrical Engineering, Sudan University of Science and Technology, Khartoum, Sudan
osmankoloum@gmail.com

[6]Department of Electrical Engineering, Sudan University of Science and Technology, Khartoum, Sudan
azzamemad28@gmail.com

[7]Department of Electrical Engineering, Sudan University of Science and Technology, Khartoum, Sudan
mhmedameen65@gmail.com

Abstract*: The power system consists of a number of synchronous generators in different power stations that rotate at synchronous speeds to feed the required loads in the case of stability. However, when these loads change or fault occurs that cause the swing of these machines due to unequal of input and output capacity of generators, the effect of this oscillation may transfer from one machine to another through the network of the system, which leads to the increase of the oscillation of some machines and out of service or damp this swing and return to stability by using one of the damping controller. In this research, the performance and efficiency of (PSS) was studied by applying it to (3-machine 9-bus) by finding the eigenvalues and time domain simulation under different operating conditions represent the system's response to low oscillations which came from low change in mechanical input capacity, The results of eigenvalue analysis and time domain proved efficient and effective of PSS in enhancing stability and increasing the percentage of damping ratio.*

.**Keywords**— Small signal stability; eigenvalue; Power System Stabilizer (PSS).

1. INTRODUCTION

Power system stability is the difficult and complex issue that facing engineers for many years. The historical review of this subject is useful for a better understanding of present-day stability problems. As a result, stability has become a major concern in power systems. Accidents of power system blackouts caused by rotor angle instability, voltage instability or frequency instability. Power system stability may be broadly defined as the ability of system to reach new point adapt with new situation [1]. The power system stability can be classified into different types: angular stability, voltage stability and frequency stability. The angular stability can be categorized into small signal stability and transient stability. Small-signal stability is the ability of the system to return to its normal operating state following a small disturbance. Investigation of this kind of stability usually involves the analysis of the linearized state space equations that define the power system dynamics. On the other hand, , transient stability is the ability of the system to return to a normal operating state following a severe disturbance, such as a single-phase or multi-phase short-circuit or a generator lost. Under these conditions, the linearized power system model is not sufficient and the nonlinear equations must be used for the analysis [2].

2. PROBLEM STATEMENT

The power system stability problem is concerned with the behavior of the synchronous machines after they have been perturbed. If the perturbation does not involve any net change in power, the machines should return to their original state. If an unbalance between the supply and demand is created by a change in load, generation, or in network conditions, a new operating state is necessary. In any case all interconnected synchronous machines should remain in synchronism if the system is stable; i.e., they should all remain operating in parallel and at the same speed. The low frequency oscillations can be initiated by small disturbance. The range of it from 0.1 -2 Hz. Small disturbance can be occur due to incremental changes in system load.

3. METHODOLOGY

The frequency modes have been determined from this eigenvalues then the PSS has been added in optimal location to increase the damping ratio which return the system in stability condition. And compared between the damping ratios before adding the PSS and after adding.

- **The eigenvalue and modal analysis module:**

Eigenvalue analysis investigates the dynamic behavior of a power system under different characteristic frequencies (modes). Specifically it provides:

- Methods to investigate long-term stability.
- Allows a deeper view into eigenvectors.
- Determines the best damping locations.
- Allows an evaluation of damping strategies.

The results of an eigenvalue analysis are given as frequency and relative damping for each oscillatory mode, and the response of the system is caused by the location of the eigenvalues. The number of eigenvalues in a power system increases with the size of it.

- **State-space representation and linearization:**

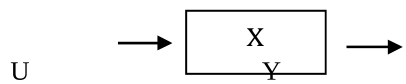

Figure 1: dynamic system

Every dynamic system can be described with a state vector x, an input vector u, and an output vector y, as in figure (1). The state vector x contains the n state variables of the dynamic system. A state variable is a variable in the system that has to be time-derived through a time simulation.

- **Eigenvectors:**

For every eigenvalue there exist two eigenvectors, right and left eigenvector. The right eigenvector gives information about the observe ability of oscillations. The left eigenvector gives information about the controllability. The combination of the right and left eigenvectors (residues) indicates the location of the damping controllers.

- **Power System Stabilizer:**

PSS can help to damp generator rotor oscillations by providing an additional input signal that produces a torque component that is in phase with the rotor speed deviation [4].It consists of a washout circuit, dynamic compensator, torsional filter and limiter as shown in figure (2). And the data of PSS used shown below.

- **PSSs parameters:**

No. of PSS	T_M	K_G	T_1	T_2	T_3	T_4	Kpss
PSS 1	10	4.415	0.6581	0.0211	0.6737	0.0230	4033.47
PSS 2	10	0.8845	0.7403	0.0299	0.9705	0.0207	1026.74

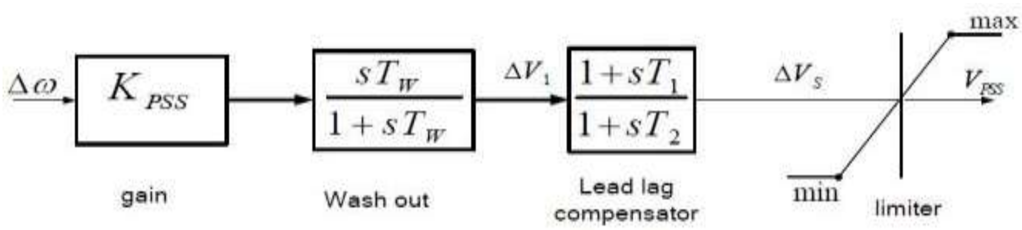

Figure 2: General representation of Power system stabilizer

4. SIMULATION AND RESULTS

In this paper the eigenvalue analysis has been represented for the multimachines system. The results obtained through simulations of the system response for different operating conditions: the system with PSS and without PSS.

- **Case Study:**

3 machines, 9-buses power system has been used to demonstrate the modal analysis of a power system. The single line diagram of the system is shown in figure (3) .

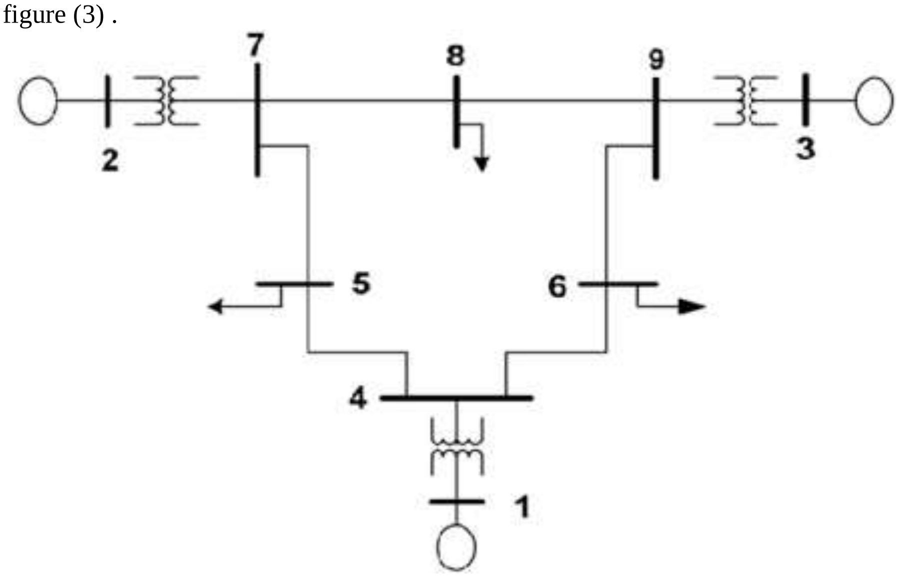

Figure 3: three machine-9bus System

- **Eigenvalue Analysis**

In this section eigenvalue method has been used to analyze the stability problem of the system in two cases.

i. Base case:

Table 1: The eigenvalues of the system without PSS at normal operation.

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-0.6856 +12.7756i	0.0536	2.0333	Local area
2	-0.6856 -12.7756i	0.0536	2.0333	Local area
3	-0.1229 + 8.2867i	0.0148	1.3189	Local area
4	-0.1229 - 8.2867i	0.0148	1.3189	Local area
5	-2.3791 + 2.6172i	0.6726	0.4165	Non swing
6	-2.3791 - 2.6172i	0.6726	0.4165	Non swing
7	-4.6706 + 1.3750i	0.9593	0.2188	Non swing
8	-4.6706 - 1.3750i	0.9593	0.2188	Non swing
9	-3.5199 + 1.0156i	0.9608	0.1616	Non swing
10	-3.5199 - 1.0156i	0.9608	0.1616	Non swing
11	-2.2008 + 0.0000i	1.0000	0	Non swing
12	-0.8845 + 0.0000i	1.0000	0	Non swing
13	0.0000 + 0.0000i	-0.0000	0.0000	Non swing
14	0.0000 - 0.0000i	-0.0000	0.0000	Non swing
15	-3.2258 + 0.0000i	1.0000	0	Non swing

Table 2: The eigenvalues of the system without PSS at light load condition.

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-0.5632 +12.8797i	0.0437	2.0499	Local area
2	-0.5632 -12.8797i	0.0437	2.0499	Local area
3	-0.0918 + 8.0362i	0.0114	1.2790	Local area
4	-0.0918 - 8.0362i	0.0114	1.2790	Local area
5	-2.2524 + 2.8443i	0.6208	0.4527	Non swing
6	-2.2524 - 2.8443i	0.6208	0.4527	Non swing
7	-4.8698 + 1.2413i	0.9690	0.1976	Non swing
8	-4.8698 - 1.2413i	0.9690	0.1976	Non swing
9	-3.6321 + 0.8351i	0.9746	0.1329	Non swing
10	-3.6321 - 0.8351i	0.9746	0.1329	Non swing
11	0.0000 + 0.0000i	-1.0000	0	Non swing
12	-0.0000 + 0.0000i	1.0000	0	Non swing
13	-2.0897 + 0.0000i	1.0000	0	Non swing
14	-0.7327 + 0.0000i	1.0000	0	Non swing
15	-3.2258 + 0.0000i	1.0000	0	Non swing

Table 3: The eigenvalues of the system without PSS at heavy load condition.

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-0.9403 +12.5445i	0.0747	1.9965	Local area
2	-0.9403 -12.5445i	0.0747	1.9965	Local area
3	-0.2454 + 8.1631i	0.0301	1.2992	Local area
4	-0.2454 - 8.1631i	0.0301	1.2992	Local area
5	-2.5874 + 2.2604i	0.7531	0.3598	Non swing
6	-2.5874 - 2.2604i	0.7531	0.3598	Non swing
7	-4.0310 + 1.3952i	0.9450	0.2221	Non swing
8	-4.0310 - 1.3952i	0.9450	0.2221	Non swing
9	-2.8585 + 1.5510i	0.8790	0.2468	Non swing
10	-2.8585 - 1.5510i	0.8790	0.2468	Non swing
11	-3.4033 + 0.0000i	1.0000	0	Non swing
12	-1.7412 + 0.0000i	1.0000	0	Non swing
13	0.0000 + 0.0000i	-0.0000	0.0000	Non swing
14	0.0000 - 0.0000i	-0.0000	0.0000	Non swing
15	-3.2258 + 0.0000i	1.0000	0	Non swing

In this case generators are provided with static exciter with no PSS. Further, constant impedance type load modal has been employed for both real and reactive components of loads. The eigenvalues, damping ratio, frequency of oscillations, and the type of mode of oscillations are shown in table (1), (2) and (3). All of the real parts are negative which mean the system is stable but it observed that the real parts and damping ratio of the system at light load are decreased which mean the system became poorly damped, but at heavy load the real parts and damping ratio increased.

ii. Controlled case:

Here the PSS controller has been added to the system however, before adding it the optimal location of PSS has been determined. From the method of design the PSS; which represented in the previous section the PSSs have been designed and added to machine 2 and machine 3 and table (4) showing system response.

Table 4: The eigenvalues of the system with PSS at normal operation.

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-62.1948 + 0.0000i	1.0000	0	Non Swing
2	-54.1848 + 0.0000i	1.0000	0	Non Swing
3	-23.5775 + 0.0000i	1.0000	0	Non Swing
4	-4.6746 +13.7283i	0.3223	2.1849	Local Area
5	-4.6746 -13.7283i	0.3223	2.1849	Local Area
6	-13.7865 + 0.0000i	1.0000	0	Non Swing
7	-4.4773 + 7.8970i	0.4932	1.2569	Local Area
8	-4.4773 - 7.8970i	0.4932	1.2569	Local Area
9	-3.8843 + 2.9517i	0.7962	0.4698	Non Swing
10	-3.8843 - 2.9517i	0.7962	0.4698	Non Swing
11	-3.8724 + 2.2456i	0.8651	0.3574	Non Swing
12	-3.8724 - 2.2456i	0.8651	0.3574	Non Swing
13	-3.8797 + 2.0749i	0.8818	0.3302	Non Swing
14	-3.8797 - 2.0749i	0.8818	0.3302	Non Swing
15	-2.1369 + 0.0000i	1.0000	0	Non Swing
16	-0.8870 + 0.0000i	1.0000	0	Non Swing
17	-0.2227 + 0.0000i	1.0000	0	Non Swing
18	0.0000 + 0.0000i	-1.0000	0	Non Swing
19	-0.0000 + 0.0000i	1.0000	0	Non Swing
20	-0.1002 + 0.0000i	1.0000	0	Non Swing
21	-3.2258 + 0.0000i	1.0000	0	Non Swing

In this case generators are provided with static exciter with PSS, all of the real parts are negative which mean the system is stable and observed that the PSSs raise the damping ratio from (1.48%) and(5.36%) to (32.23%) and (49.32%) for local area mode as shown in figure (4).

Figure 4: Compression of damping ratio between base case and controlled case during normal operation.

Table 5: The eigenvalues of the system with PSS at light load condition

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-62.1988 + 0.0000i	1.0000	0	Non Swing
2	-54.0760 + 0.0000i	1.0000	0	Non Swing
3	-24.4580 + 0.0000i	1.0000	0	Non Swing
4	-5.0416 +14.1434i	0.3358	2.2510	Local Area
5	-5.0416 -14.1434i	0.3358	2.2510	Local Area
6	-13.9577 + 0.0000i	1.0000	0	Non Swing
7	-4.0785 + 8.1202i	0.4488	1.2924	Local Area
8	-4.0785 - 8.1202i	0.4488	1.2924	Local Area
9	-4.9056 + 2.2572i	0.9084	0.3592	Non Swing
10	-4.9056 - 2.2572i	0.9084	0.3592	Non Swing
11	-2.4835 + 3.3720i	0.5930	0.5367	Non Swing
12	-2.4835 - 3.3720i	0.5930	0.5367	Non Swing
13	-3.8515 + 1.2860i	0.9485	0.2047	Non Swing
14	-3.8515 - 1.2860i	0.9485	0.2047	Non Swing
15	-2.0565 + 0.0000i	1.0000	0	Non Swing
16	-0.7334 + 0.0000i	1.0000	0	Non Swing
17	-0.1650 + 0.0000i	1.0000	0	Non Swing
18	-0.1002 + 0.0000i	1.0000	0	Non Swing
19	-0.0000 + 0.0000i	1.0000	0	Non Swing
20	0.0000 + 0.0000i	-1.0000	0	Non Swing
21	-3.2258 + 0.0000i	1.0000	0	Non Swing

Table 6: The eigenvalues of the system with PSS at heavy load condition.

SL_ Number	Eigenvalue	Damping Ratio	Frequency (Hz)	Nature of mode
1	-61.8456 + 0.0000i	1.0000	0	Non Swing
2	-53.6573 + 0.0000i	1.0000	0	Non Swing
3	-24.3436 + 0.0000i	1.0000	0	Non Swing
4	-3.3678 +13.1730i	0.2477	2.0965	Local Area
5	-3.3678 -13.1730i	0.2477	2.0965	Local Area
6	-9.9099 + 4.0856i	0.9245	0.6503	Local Area
7	-9.9099 - 4.0856i	0.9245	0.6503	Local Area
8	-8.0400 + 0.0000i	1.0000	0	Non Swing
9	-3.3208 + 5.6758i	0.5050	0.9033	Non Swing
10	-3.3208 - 5.6758i	0.5050	0.9033	Non Swing
11	-3.8480 + 1.8600i	0.9003	0.2960	Non Swing
12	-3.8480 - 1.8600i	0.9003	0.2960	Non Swing
13	-2.6940 + 1.7539i	0.8380	0.2791	Non Swing
14	-2.6940 - 1.7539i	0.8380	0.2791	Non Swing

15	-2.9949 + 0.0000i	1.0000	0	Non Swing
16	-1.7353 + 0.0000i	1.0000	0	Non Swing
17	-0.2976 + 0.0000i	1.0000	0	Non Swing
18	-0.1001 + 0.0000i	1.0000	0	Non Swing
19	0.0000 + 0.0000i	-1.0000	0	Non Swing
20	-0.0000 + 0.0000i	1.0000	0	Non Swing
21	-3.2258 + 0.0000i	1.0000	0	Non Swing

Also in this case when light load added to the system the damping ratio increase from (4.37%), (1.14%) to (33.58%), (44.88%) for the two modes, when heavy load added to the system the damping ratio increase from (7.47%), (3.01) to (24.77%), (92.45%) for the two modes.

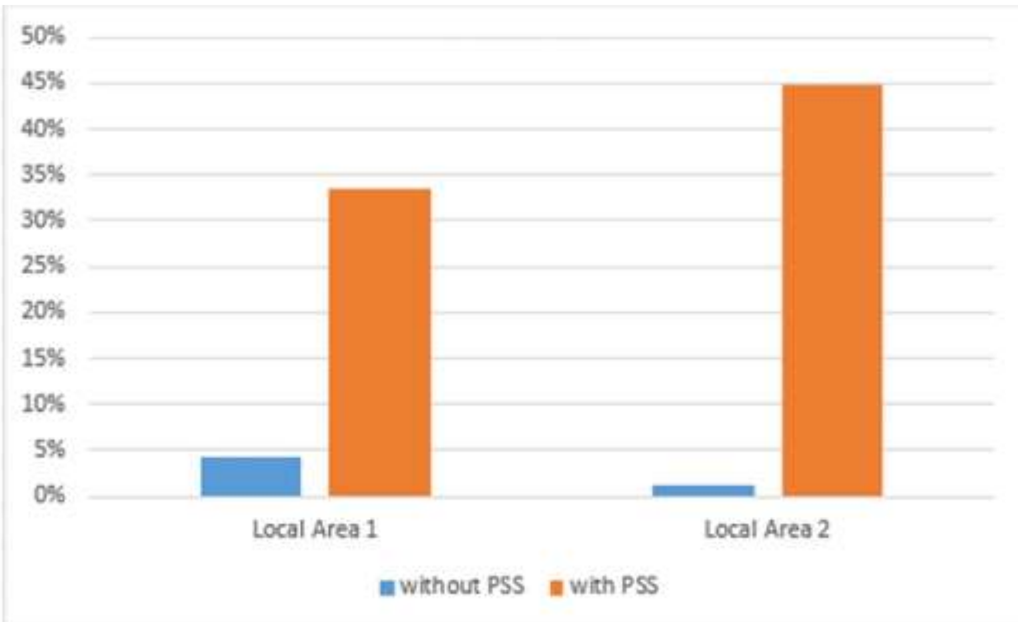

Figure 5: Compression of damping ratio between base case and controlled case during light load operation

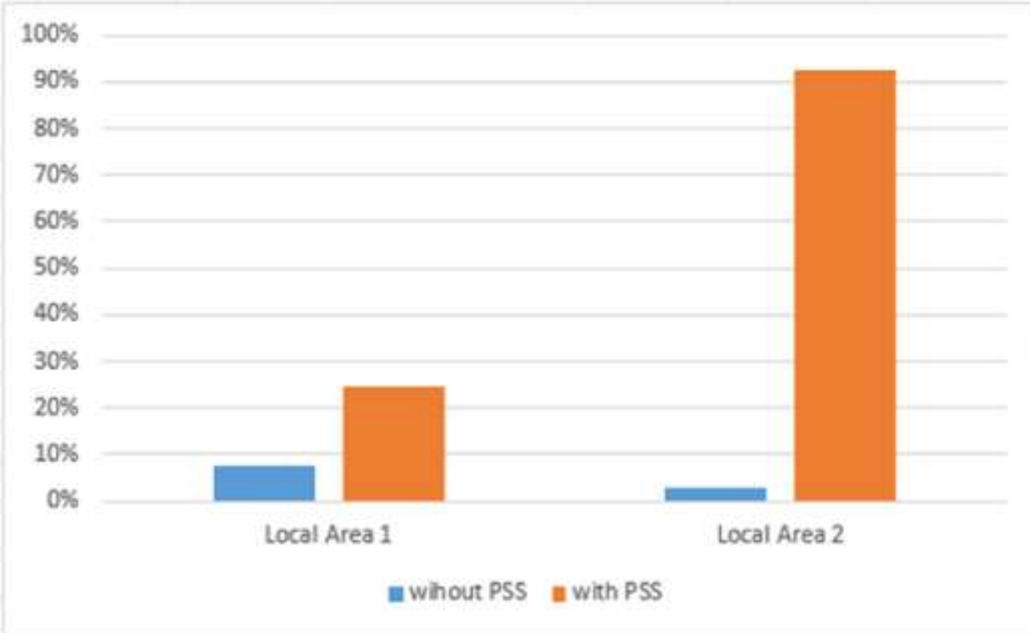

Figure 6: Compression of damping ratio between base case and controlled case during heavy load operation

5. CONCLUSION

The problem of low frequency oscillations in power systems has been addressed in this research by using eigenvalue method. The system in base case (without PSS) was stable at normal condition but has poor damping of electromechanical low frequency oscillation of local modes. To provide adequate damping ratio, the power system stabilizer has been designed by using phase compensation technique. The optimal location of multi PSS controllers is important issue to avoid the destabilizing effect of them. Participation factors which represent the contribution of machines in specific modes is used to identifying the optimal locations. After that the effect of PSS has been discussed for small and large disturbances. Finally the power system stabilizer (PSS) is a cost effective way of improving the damping of electromechanical oscillations of rotor and return the stability to the system.

6. REFERENCES

[1] P.Kunder," Power system stability and control", McGraw-Hill companies, university of Toronto, 1994.
[2] D P Kothari, I J nagrath, "Modern Power System Analysis", third edition
[3] Chapman Stephen. Electric machinery and power system fundamentals. Boton: McGraw hill.
[4] Debasish Mondal, Abhijit Chakrabarti, Aparajita Senguta, "Power System Small Signal Stability Analysis and Control"
[5] K.R. Padiyar, Power System Dynamics - Stability and Control, BS Publications, Hyderabad, India, 2002.
[6] P.M. Anderson, A.A.Fouad "Power System Stability and Control".

Authors

Bahaaldeen Mohammed

Teaching Assistant at Alzaiem Alazhari University
B. Science; Electrical Engineering
(Electrical Power)
Alzaiem Alazhari University, Khartoum,
Sudan

Badreldeen Abdallah
B. Science; Electrical Engineering
(Power and Machines)
Sudan University of Science and Technology, Khartoum, Sudan

Mohammed Elmubarak Adam

Teaching Assistant at University of Bahri
B. Science; Electrical and Electronics Engineering
(Electrical Power)
University of Bahri, Khartoum, Sudan

Abubakr Mustafa
B. Science; Electrical Engineering
(Power and Machines)
Sudan University of Science and Technology, Khartoum, Sudan

Osman Osman
B. Science; Electrical Engineering
(Power and Machines)
Sudan University of Science and Technology, Khartoum, Sudan

Azzam Abdlmoneam
B. Science; Electrical Engineering
(Power and Machines)
Sudan University of Science and Technology, Khartoum, Sudan

Mohammed Mohammed
B. Science; Electrical Engineering
(Power and Machines)
Sudan University of Science and Technology, Khartoum, Sudan