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Comparative Evaluation Of Sssc And Statcom Facts Devices Power Transfer Capability Enhancement On The Nigerian 330KV Power Network

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***Abstract*— In this paper, comparative evaluation of SSSC and STATCOM FACTS devices power transfer capability enhancement on the Nigerian 330KV power network is presented. The study was carried out using the dataset acquired from the National Control Center in Oshogbo, Osun state. The dataset covered 12 buses and the analysis was conducted in Matlab using the PSAT toolbox. The network was modeled in the PSAT environment and analyzed with the SSSC FACTS device and then with the STATCOM FACT device. The results showed the while 6 buses were below the acceptable 0.95 pu without any FACTS device, only one bus at Ihovbor (bus 8) was below the 0.95 pu after enhancement was done with the SSSC device while three buses at Benin (bus 6), Ihovbor (bus 8) and New heaven (bus 9) were below the 0.95 pu after enhancement was done with the STATCOM device. In addition there is 13.8 % mean enhancement in the voltage profile of the power network buses with SSSC and 12.6 % mean enhancement with STATCOM. Essentially, the SSSC FACTS device gave better enhancement in the voltage profile of the power network buses. The results on the active power transfer show that 54.9 % average enhancement in active power transfer capability was realised with SSSC device while 46.4 % average enhancement in active power transfer capability was realised with STATCOM device. Similarly, the results the reactive power show that 58.2 % average enhancement in reactive power transfer capability was realised with SSSC device while 42.6% average enhancement in reactive power transfer capability was realised with STATCOM device. Essentially, the SSSC FACTS device gave better enhancement in both the active reactive power transfer capabilities of the power lines. Therefore, the SSSC was preferred over the STATCOM FACT device for enhancement of the performance of the case study Nigerian 330kv power network.**

Keywords*— Flexible AC Transmission Systems (FACTS), Nigerian 330kv Power Network, Static Synchronous Series Compensator (SSSC), FACTS Device, STATic synchronous COMpensator (STATCOM)

1. Introduction

In the electric power sector of every nation, the need to provide clean and sufficient electric power supply to the entire populace is paramount [1,2,3]. However, such objective is rarely satisfied in many of the developing countries in Africa. In Nigeria for instance, the population and electric power demand growth outruns the nation electric energy generation and supply capacity [4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19]. There is also an additional factor; the rise in electric-power dependence across the globe due to polices , changes in lifestyle and technological solutions that demand electric-powered devices and systems [20,21, 22,23, 24,25, 26,27, 28,29, 30,31,32,33,34,35,36,37]. This has given rise to excessive expenditure by the citizens on alternative energy sources. Solar and wind power systems for instance are among the most commonly adopted alternative to the national grid [38,38, 40,41, 42,43, 44, 45, 46,47,48, 49,50, 51,52,53,54,55,56,57,58,59,60,61,62,63,64,65]. However, the cost of acquiring and sustaining solar power system is very high when compared with the cost of energy from the national grid [66,67,68,69,70]. Similarly the diesel and other fossil fuel alternative energy sources are also more expensive than the energy from the national grid. In addition, such energy sources are discouraged in this era of demand for clean energy solutions.

Consequently, one of the promising solutions is to enhance the efficiency of the existing power system network. In this

paper, enhancement of the power transfer capability of existing power network is studied. By enhancing the power transfer capability, more percentage of the generated energy in the system is delivered to the end users thereby reducing the power shortage problem. Specifically, in this paper, comparative evaluation of static synchronous series compensator (SSSC) and STATic synchronous COMpensator (STATCOM) FACTS devices for power transfer capability enhancement on the Nigerian 330KV power network is presented [71,72,73]. The case study power network is modeled in the PSAT software environment and analyzed with the SSSC FACTS device and then with the STATCOM FACTS device. The essence of the study is to identify from empirical data and simulated analysis which of the two FACTS devices considered can perform better in power transfer enhancement for the case study power network.

2. Methodology

The focus of the paper is to compare the ability of SSSC and STATCOM FACTS devices to enhance the power transfer capability of the Nigerian 330kv power network. The study is based on the mapped of the segment of the Nigerian 330kV power transmission network considered in the study (as shown in Figure 1) with the voltage profile of the 12 buses in the power network (shown in Figure 2) along with the active and reactive power transfer on the power network lines (shown in Figure 3). The power network data graphs (Figure 2 and Figure 3) were generated from the excel dataset obtained from the National Control Center in Oshogbo, Osun state. The data was specifically for the Nigerian 330kV transmission power network segment which has 12 buses located in places that includes Benin, Delta, Ihovbor, Sapele, Aladja,Asaba, Ontisha, Okpai, AlaojiT.S., Alaoji G.S, New-heaven and Afam (as shown in Figure 1). The model of the power transmission network.in PSAT is given in PSAT. The PSAT toolbox in Matlab software was also used to model and analyze the power network power transfer capability with SSSC FACTS device and later with STATCOM FACTS device.

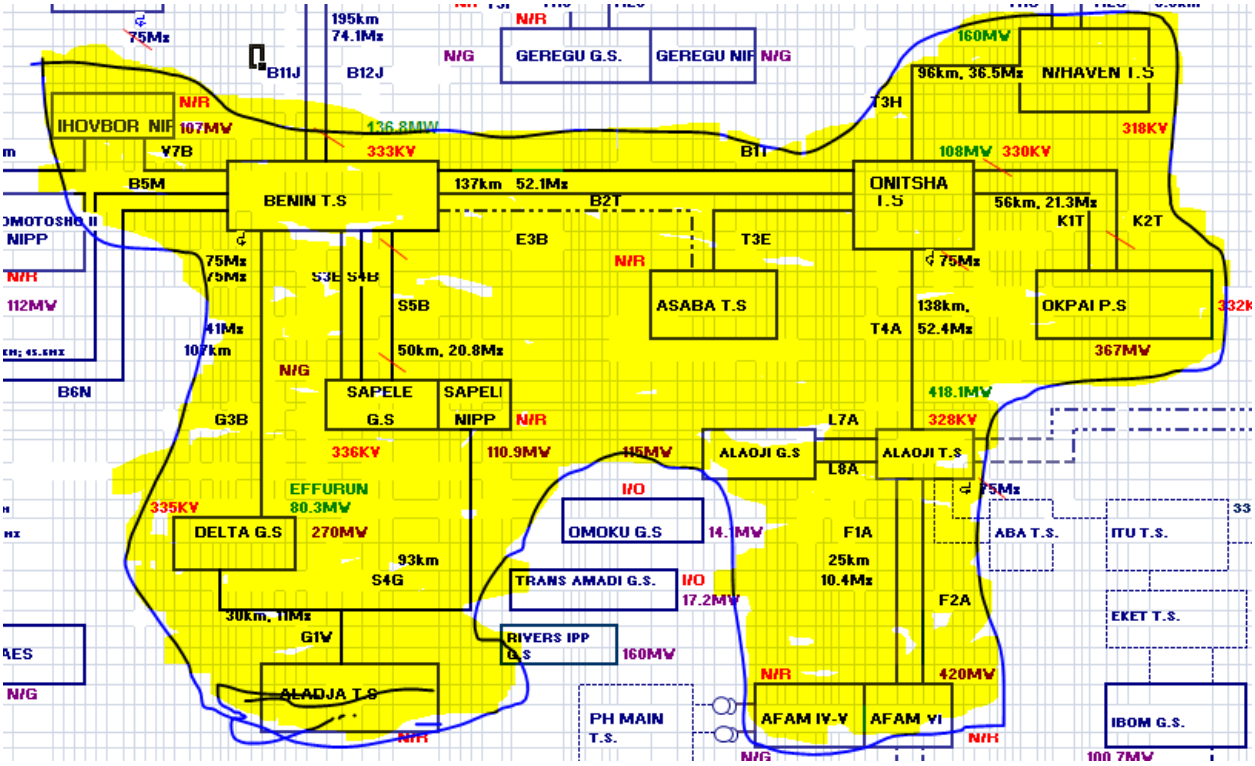

Figure 1: The mapped of the segment of the Nigerian 330kV power transmission network considered in the study

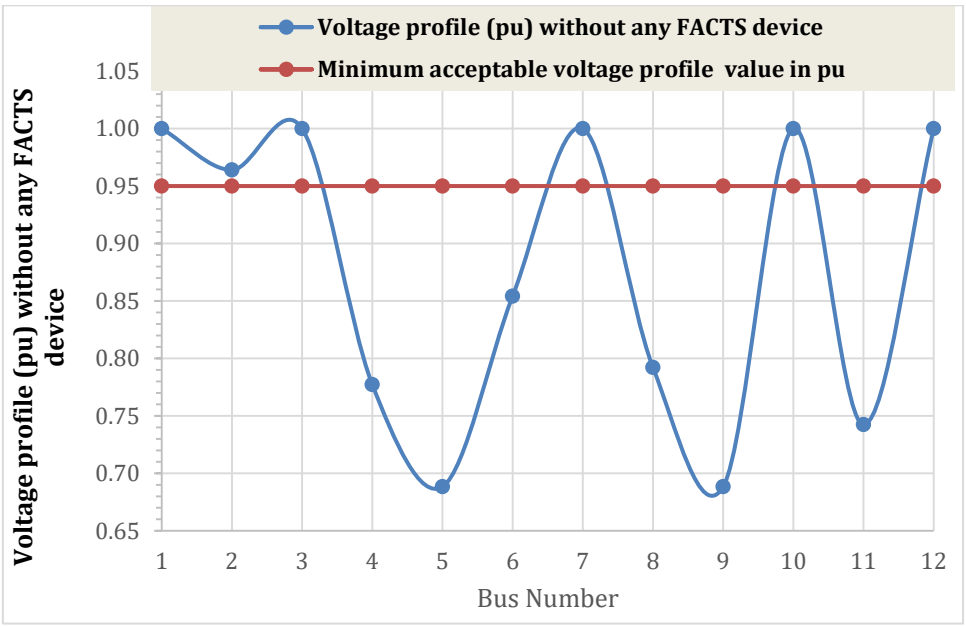

Figure 2 The graph showing the voltage profile of the buses in the case study power network

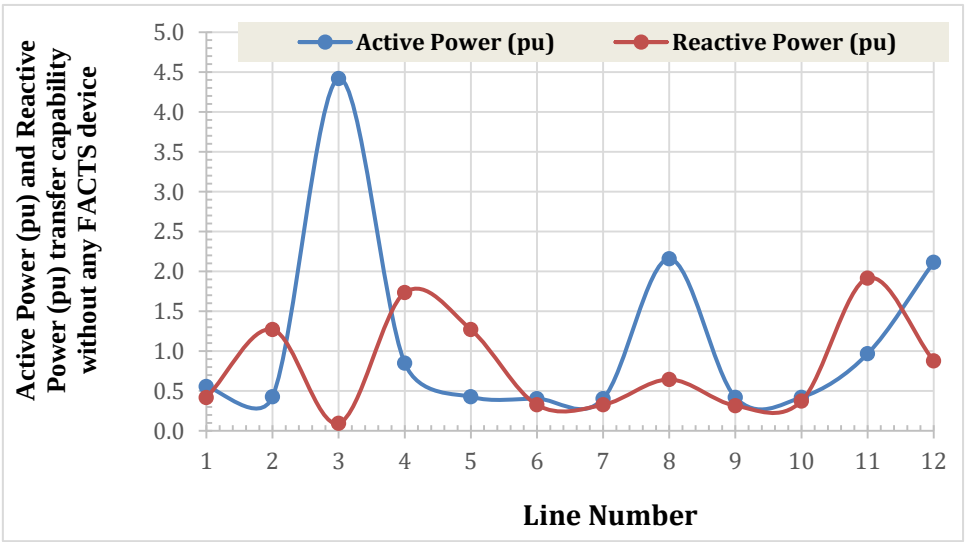

Figure 3 The graph showing the active and reactive power transfer capability of the lines in the case study power network

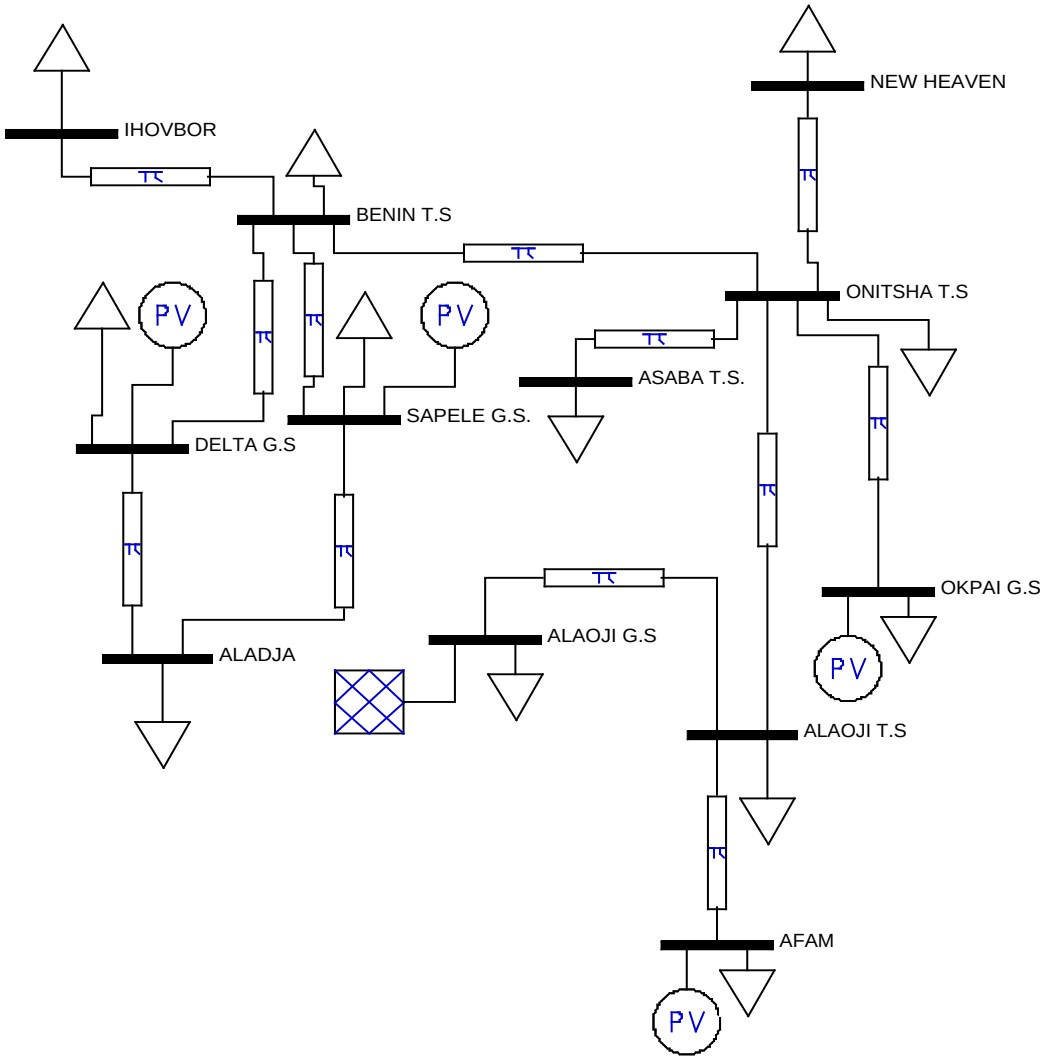

Figure 4: The model of the power transmission network.in PSAT

3. Results and discussion

3.1 The results of enhancement in the voltage profile of the power network buses

The PSAT analysis results showing the voltage profile (pu) of the power network without any FACTS device, with SSSC device and with STACOM device are presented in Table 1 and Figure 5. The data in Table 1 and Figure 5 show that without the FACTS device, about half of the buses in the network have voltage profiles below the minimum allowable threshold of 0.95 pu. Also, the average voltage profile of the network buses without the FACTS device is 0.8756 pu. However, with the introduction of the SSSC device, the average voltage profile of the network buses increased to 0.9769 pu while the the average voltage profile of the network buses with the STATCOM device is 0.9676 pu. The results showed the while 6 buses were below the acceptable 0.95 pu without any FACTS device, only one bus at Ihovbor (bus 8) was below the 0.95 pu after enhancement was done with the SSSC device while three buses at Benin (bus 6), Ihovbor (bus 8) and New heaven (bus 9) were below the 0.95 pu after enhancement was done with the STATCOM device. In addition, the graph of the percentage enhancement in the voltage profile of the power network buses with SSSC device and with STACOM device is shown in Figure 6. The results in Figure 6 show that there is 13.8 % mean enhancement in the voltage profile of the power network buses with SSSC and 12.6 % mean enhancement with STATCOM. Essentially, the SSSC FACTS device gave better enhancement in the voltage profile of the power network buses.

Table 1 The results showing the voltage profile (pu) without any FACTS device, with SSSC device and with STACOM device

Bus number	Bus Location	Voltage profile (pu) without any FACTS Device	Voltage profile (pu) with SSSC	Voltage profile (pu) with STACOM
1	Afam	1.0000	1.0000	1.0000
2	Aladja	0.9640	0.9714	0.9644
3	Alaoji G.S	1.0000	1.0000	1.0000
4	Alaoji T.S	0.7773	0.9632	0.9544
5	Asaba	0.6884	0.9833	0.9682
6	Benin	0.8542	0.9500	0.9311
7	Delta	1.0000	1.0000	1.0000
8	Ihovbor	0.7921	0.9311	0.9113
9	New heaven	0.6884	0.9499	0.9224
10	Okpai	1.0000	1.0000	1.0000
11	Onitsha	0.7424	0.9744	0.9599
12	Sapele	1.0000	1.0000	1.0000
	MEAN	**0.8756**	**0.9769**	**0.9676**

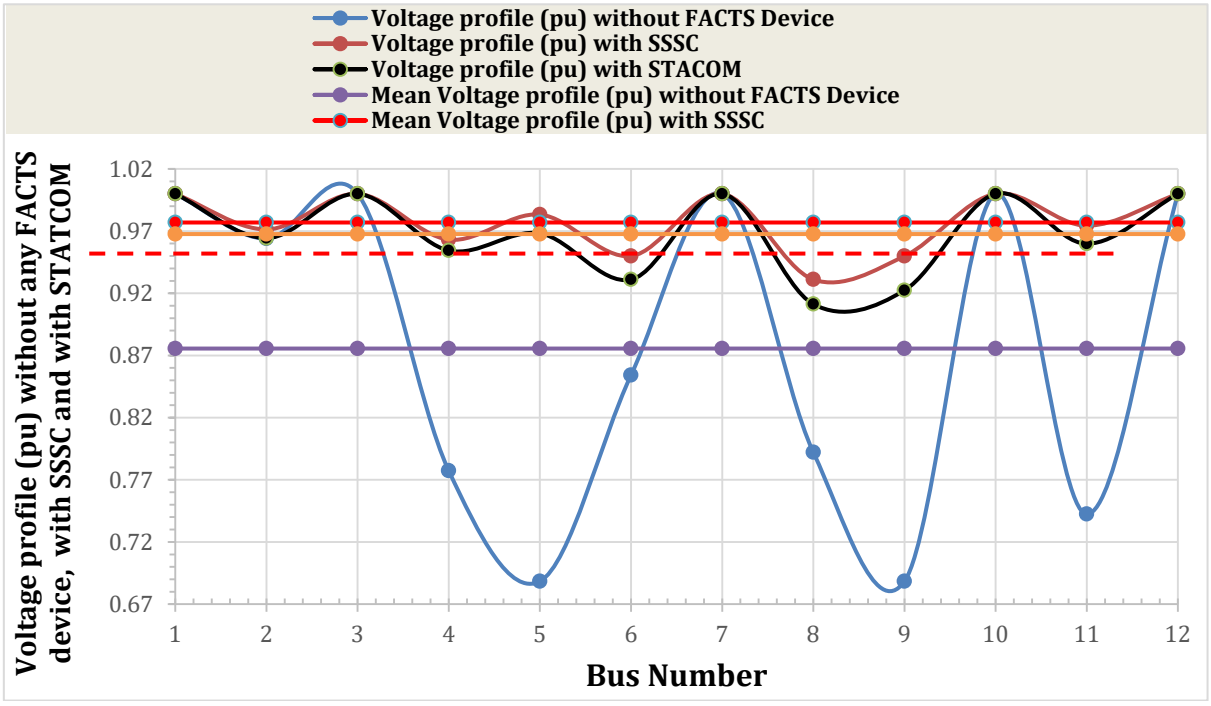

Figure 5: The graph of the voltage profile (pu) of the power network buses without any FACTS device, with SSSC device and with STACOM device

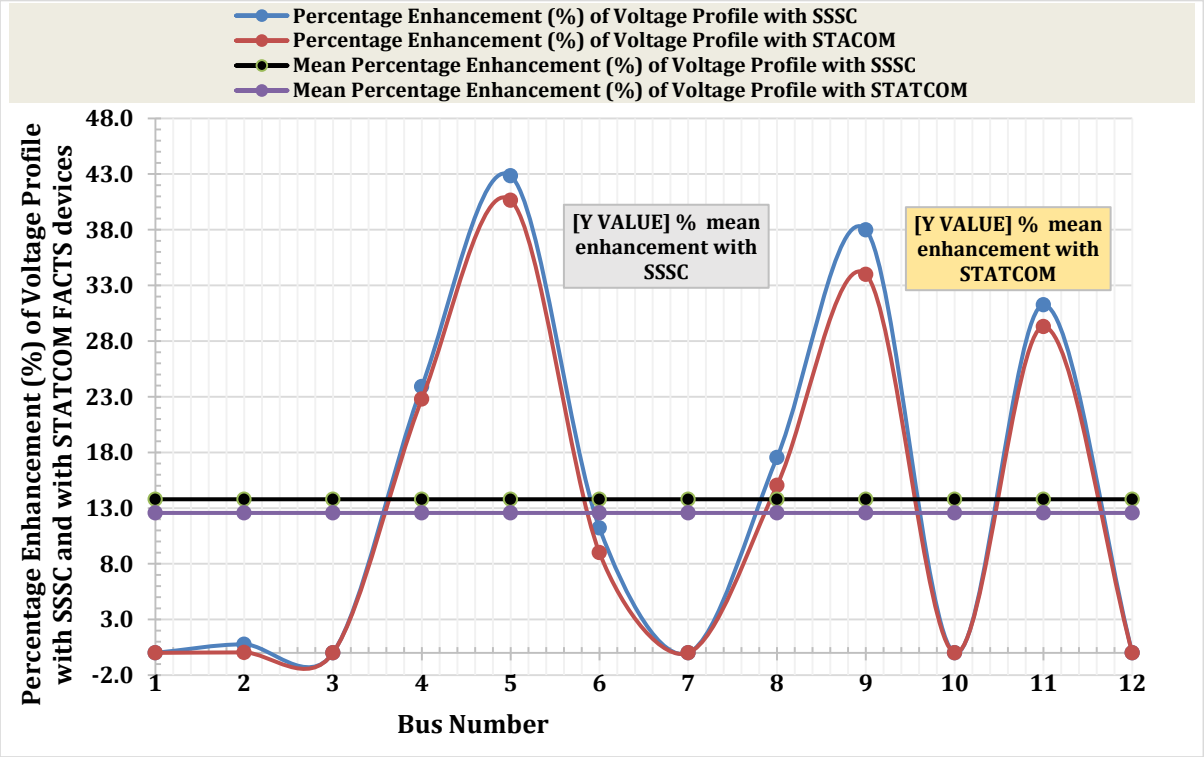

Figure 6: The graph of the percentage enhancement in the voltage profile of the power network buses with SSSC device and with STACOM device

3.2 The results of enhancement in the active and reactive power transfer in the power network lines

The results showing the active power transfer without any FACTS device, with SSSC device and with STACOM device are presented in Table 2 and Figure 7. Again, the results showing the percentage enhancement in the active power transfer capability of the power lines with SSSC device and with STACOM device are presented in Table 3 and Figure 8. The results show that 54.9 % average enhancement in active power transfer capability was realised with SSSC device while 46.4 % average enhancement in active power transfer capability was realised with STATCOM device. Essentially, the SSSC FACTS device gave better enhancement in the active power transfer capabilities of the power lines.

Table 2 The results showing the active power transfer of the power lines without any FACTS device, with SSSC device and with STACOM device

Line	From Bus	To Bus	Active Power (pu) without any FACT Device	Active power (pu) with SSSC	Active Power (pu) with STATCOM
1	'IHOVBOR'	'BENIN T.S'	0.5561	0.9523	0.8723
2	'BENIN T.S'	'DELTA G.S'	0.4273	0.6335	0.5992
3	'ALAOJI T.S'	'ALAOJI G.S'	4.4179	4.5112	4.2117
4	'ALAOJI T.S'	'AFAM'	0.8498	0.9088	0.9008
5	'BENIN T.S'	'SAPELE G.S.'	0.4273	0.8273	0.807
6	'DELTA G.S'	'ALADJA'	0.4027	0.9088	0.9
7	'SAPELE G.S.'	'ALADJA'	0.4027	0.8917	0.8331
8	'ONITSHA T.S'	'BENIN T.S'	2.1571	2.2994	2.1014
9	'NEW HEAVEN'	'ONITSHA T.S'	0.4201	0.6422	0.5833
10	'ONITSHA T.S'	'ASABA T.S.'	0.42	0.9114	0.8775
11	'ONITSHA T.S'	'OKPAI G.S'	0.9666	0.9987	0.9117
12	ONITSHA T.S'	'ALAOJI T.S'	2.114	2.3314	2.114

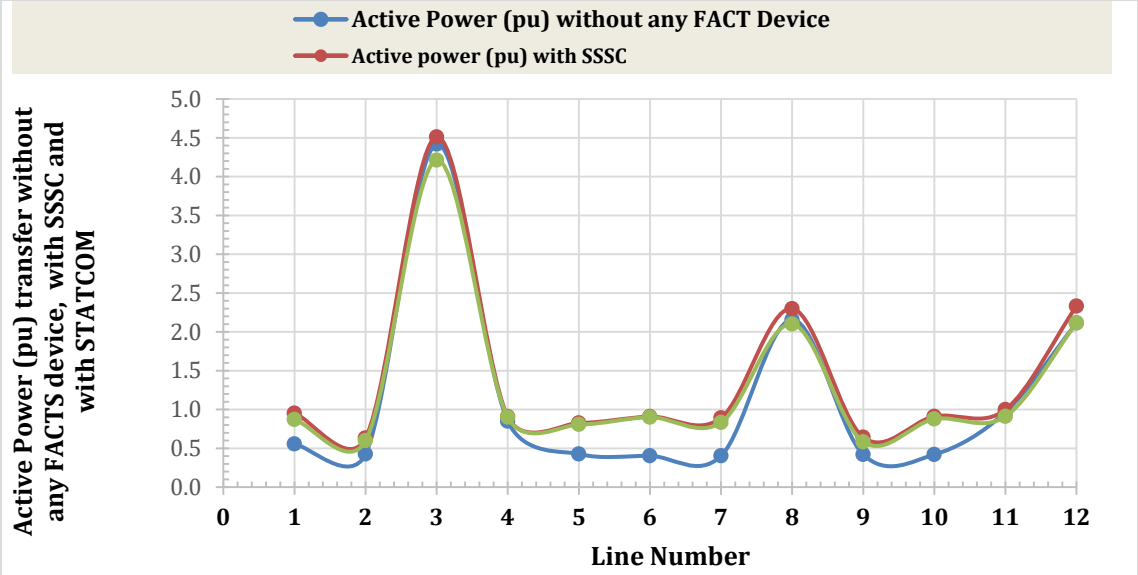

Figure 7: The graph of the active power transfer capability of the power lines without any FACTS device, with SSSC device and with STACOM device

Table 3 The results showing the percentage enhancement in the active power transfer capability of the power lines with SSSC device and with STACOM device

Line Number	Percentage enhancement (%) in Active Power Transfer with SSSC	Percentage enhancement (%) in Active Power Transfer with STATCOM
1	71.2	56.9
2	48.3	40.2
3	2.1	-4.7
4	6.9	6.0
5	93.6	88.9
6	125.7	123.5
7	121.4	106.9
8	6.6	-2.6
9	52.9	38.8
10	117.0	108.9
11	3.3	-5.7
12	10.3	0.0
Mean	54.9	46.4

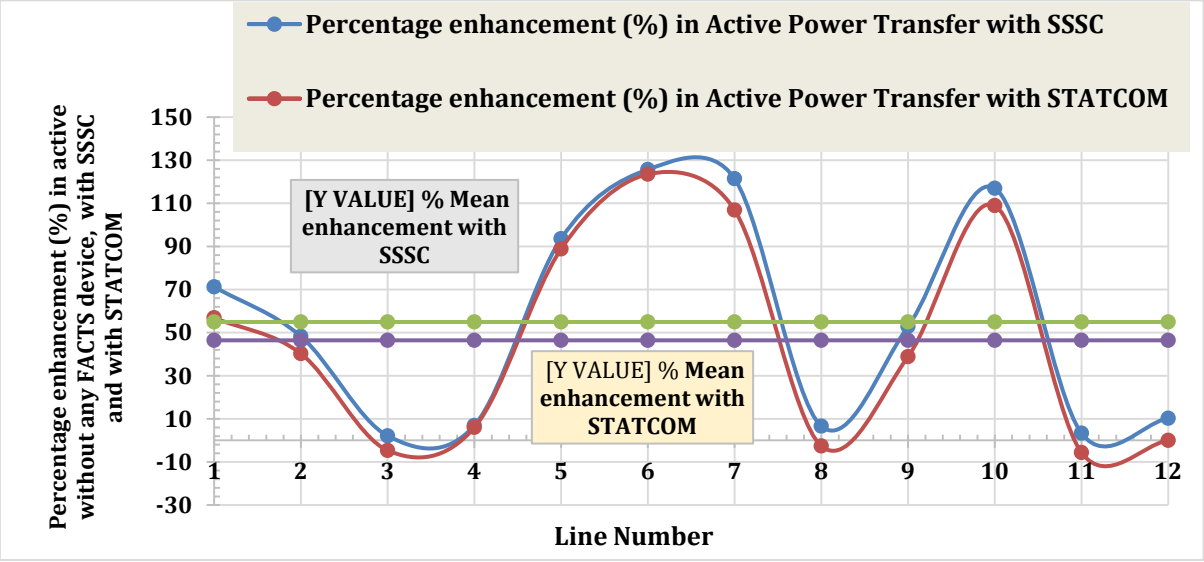

Figure 8: The graph of the percentage enhancement in the active power transfer capability of the power lines with SSSC device and with STACOM device

The results showing the reactive power transfer without any FACTS device, with SSSC device and with STACOM device are presented in Table 4 and Figure 9. Again, the results showing the percentage enhancement in the reactive power transfer capability of the power lines with SSSC device and with STACOM device are presented in Table 5 and Figure 10. The results show that **58.2 %** average enhancement in reactive power transfer capability was realised with SSSC device while **42.6%** average enhancement in reactive power transfer capability was realised with STATCOM device. Essentially, the SSSC FACTS device gave better enhancement in the reactive power transfer capabilities of the power lines.

Table 4 The results showing the reactive power transfer of the power lines without any FACTS device, with SSSC device and with STACOM device

Line	From Bus	To Bus	Reactive Power (pu) without any FACT Device	Reactive power (pu) with SSSC	Reactive Power (pu) with STATCOM
1	'IHOVBOR'	'BENIN T.S'	0.4171	0.6871	0.6113
2	'BENIN T.S'	'DELTA G.S'	1.2706	1.4111	1.3441
3	'ALAOJI T.S'	'ALAOJI G.S'	0.0944	0.2933	0.2422
4	'ALAOJI T.S'	'AFAM'	1.7333	1.9174	1.7133
5	'BENIN T.S'	'SAPELE G.S.'	1.2706	1.5664	1.4664
6	'DELTA G.S'	'ALADJA'	0.3259	0.5494	0.5196
7	'SAPELE G.S.'	'ALADJA'	0.3259	0.7709	0.7204
8	'ONITSHA T.S'	'BENIN T.S'	0.644	0.9947	0.9197
9	'NEW HEAVEN'	'ONITSHA T.S'	0.3151	0.4553	0.4152
10	'ONITSHA T.S'	'ASABA T.S.'	0.3727	0.6214	0.5345
11	'ONITSHA T.S'	'OKPAI G.S'	1.9149	1.9923	1.8921
12	ONITSHA T.S'	'ALAOJI T.S'	0.877	0.9012	0.8002

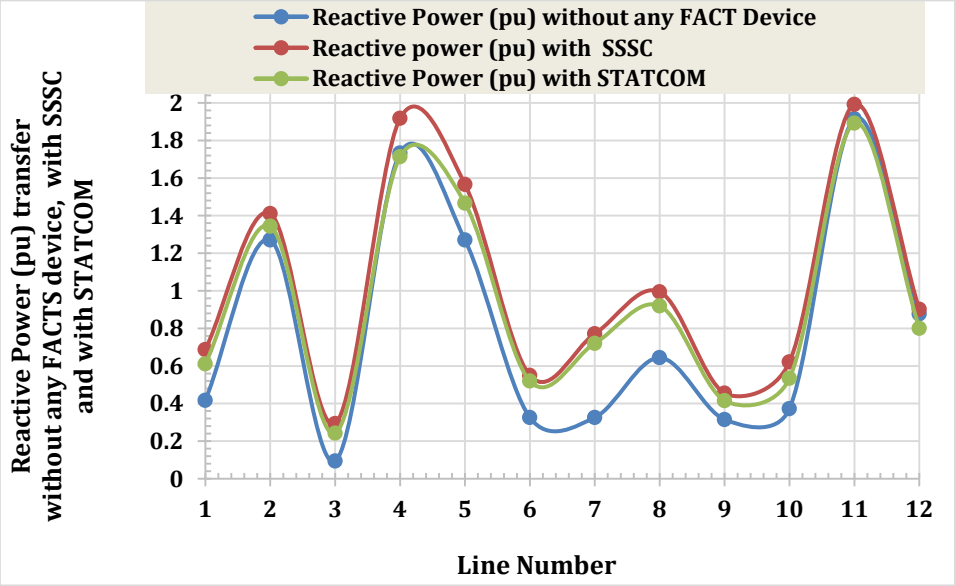

Figure 9: The graph of the reactive power transfer capability of the power lines without any FACTS device, with SSSC device and with STACOM device

Table 5 The results showing the percentage enhancement in the reactive power transfer capability of the power lines with SSSC device and with STACOM device

Line	**Percentage enhancement (%) in Reactive Power Transfer with STATCOM**	**Percentage enhancement (%) in Reactive Power Transfer with SSSC**
1	64.7	46.6
2	11.1	5.8
3	210.7	156.6
4	10.6	-1.2
5	23.3	15.4
6	68.6	59.4
7	136.5	121.0
8	54.5	42.8
9	44.5	31.8
10	66.7	43.4
11	4.0	-1.2
12	2.8	-8.8
Mean	58.2	42.6

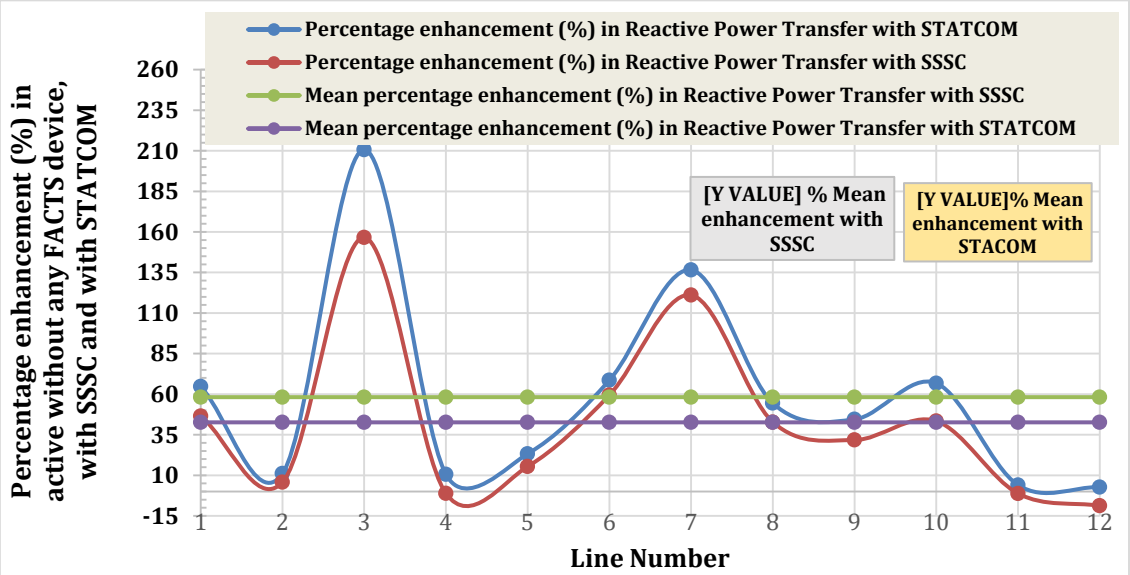

Figure 10: The graph of the percentage enhancement in the reactive power transfer capability of the power lines with SSSC device and with STACOM device

4. Conclusion

The ability of SSSC and STATCOM FACTS devices to enhance the voltage profile and power transfer capability of the Nigerian 330kv power network is presented using the dataset acquired from the National Control Center in Oshogbo, Osun state. The dataset covered 12 buses and the analysis was conducted in Matlab using the PSAT toolbox. The network was modeled in the PSAT environment and analyzed with the SSSC FACTS device and then with the STATCOM FACT device. The results of the voltage profile enhancements and power transfer enhancements with each of the FACTS device are noted and compared.

In all, the SSSC gave better voltage profile enhancements for the buses in the power network, as well as better active and reactive power transfer capabilities for the power lines. Therefore, the SSSC was preferred over the STATCOM FACT device for enhancement of the performance of the case study Nigerian 330kv power network.

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