Analysis Of Voltage Profile And Power Transfer Capability Enhancement On Nigeria 330kv Transmission Power Network Using Statcom Facts Device

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***Abstract*— In this paper, analysis of voltage profile and power transfer capability enhancement on Nigeria 330KV transmission power network using STATic synchronous COMpensator (STATCOM) Flexible AC Transmission Systems (FACTS) is presented. The selected transmission power network has 12 buses that include Benin, Sapele, Aladja, Delta, Ihovbor, Asaba, Ontisha, Alaoji G.S, Okpai, AlaojiT.S., Afam and New-heaven. The transmission power network buses were modelled on PSAT in order to determine the possible enhancements achievable in voltage profile and power transfer in the studied network due to the use of STACOM FACTS device. Specifically, the simulation analysis of the power network was first conducted without the STACOM FACTS device and then the simulation analysis was conducted with STACOM FACTS device. The results show that the STATCOM FACT device gave an average of 12.6 % improvement in the voltage profile of the buses along with an average of 46.4% improvement in the active power transfer and also an average of 42.6% improvement in the reactive power transfer capability of the lines.In all, the study has shown that STATCOM FACTS device can be effectively improve the voltage profile and overall power transfer capability of the Nigeria 330KV transmission power network considered in the study.**

Keywords*— Voltage Profile, Reactive Power Transfer, Flexible AC Transmission Systems (FACTS), Power Transfer Capability, Active Power Transfer, STATic synchronous COMpensator (STATCOM)

1.0 Introduction

In every developing nation, the energy sector is under running challenges[1,2]. One of the major causes of the energy problem is the steady growth in the demand population and applications and the limited portion of the population that have access to the national grid [3,4, 5, 6,7,8,9,10,11,12,13,14,15,16,17]. Increasing population of electric-power systems and solutions continue to be developed due to advancements the electronics and communication technologies [18,19,20,21,22,23]. Today cashless policy, smart government, wireless sensor networks, GSM-based solutions, satellite technology driven applications and many other software and embedded system solutions are among the things that lead to increasing dependence on electricity [24,25,26,27,28,29,30, 31,32, 33,34, 35,36, 37,38, 39,40, 41,42, 43, 44, 45]. In other to improve on the power generation, distributed energy generation system has been used in many places to accommodate energy generation from different source and feeding the distributed generation system to a common transmission network [46, 47, 48, 49, 50, 51]. In places like Nigeria, solar power, wind power supply and biomass-based energy generating system have been considered [52,53, 54,55, 56,57, 58,59, 60,61, 62,63, 64,65, 66,67, 68,69, 70,71, 72,73, 74,75, 76,77,78]. In all, the limitation of power transfer capability of the transmission networks presents a major problem in harnessing the potential of distributed power generation system [79,80,81,82].

Essentially, the need to satisfy growing demand is a recurring problem which also causes some problems on the power supply network. Overloading of the transmission and distribution lines and unbalanced loads on the lines significantly affect the voltage profiles of the lines and their power transfer capabilities. In this regards, notable FACTS devices are presently being used to address the problem. Consequently, in this paper, analysis of voltage profile and power transfer capability enhancement on Nigeria 330KV transmission power network using STATic synchronous COMpensator (STATCOM) Flexible AC Transmission Systems (FACTS) is presented. The transmission power network buses were modelled on PSAT software in order to determine the possible enhancements achievable in voltage profile and power transfer in the studied network due to the use of STACOM FACTS device. In all, the extent to which the STATCOM FACTS device can enhance power transfer capability of the case study power network is quantified and determined in terms of percentage improvement in the voltage profile of the buses, percentage improvement in the active power transfer and also percentage improvement in the reactive power transfer capability of the case study power network.

2. Methodology

2.1 The Nigerian 330kV transmission power network Data

The National Control Center located in Oshogbo, Osun State provided data on selected buses in the area of interest on the Nigerian 330kV transmission power network. The buses selected include Benin, Sapele, Aladja, Delta, Ihovbor, Asaba, Ontisha, Alaoji G.S, Okpai, AlaojiT.S., Afam and New-heaven and they ae mapped in Figure 1.

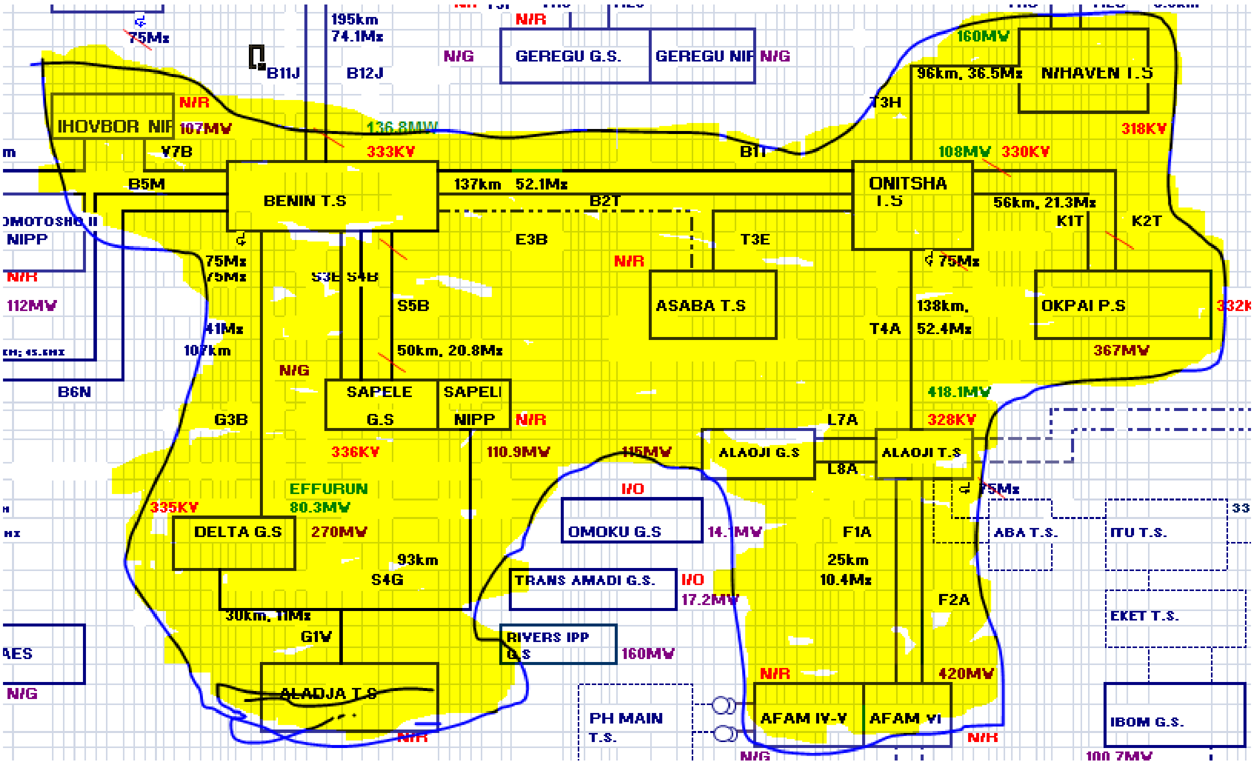

Figure 1: The layout of the area of interest on the Nigerian 330kV power system network showing the buses and their locations.

The data on the voltage profile of the 12 buses that make up the case study power network without the STACOM FACTS device is presented in Figure 2. From the bar chart in Figure 2, it is seen that the voltage profile of buses 4,5,6,8,9 and 11 are below the acceptable range of values which is).95 to 1.05. The active and reactive power transfer dataset for the power network without the STACOM FACTS Device is given in Table 1 while the scatter plot of the active and reactive power for the Lines without the STACOM FACTS device is shown in Figure 3 and Figure 4 respectively.

The case study Nigerian 330kV transmission power network segment consisting of 12 buses was modelled on PSAT (as shown in Figure 5 with STACOM FACTS device connected) in order to determine the improvement in voltage profile and power transfer in the studied network due to the use of STACOM FACTS device. Specifically, the simulation analysis of the power network was first conducted without the STACOM FACTS device and then the simulation analysis was conducted with STACOM FACTS device.

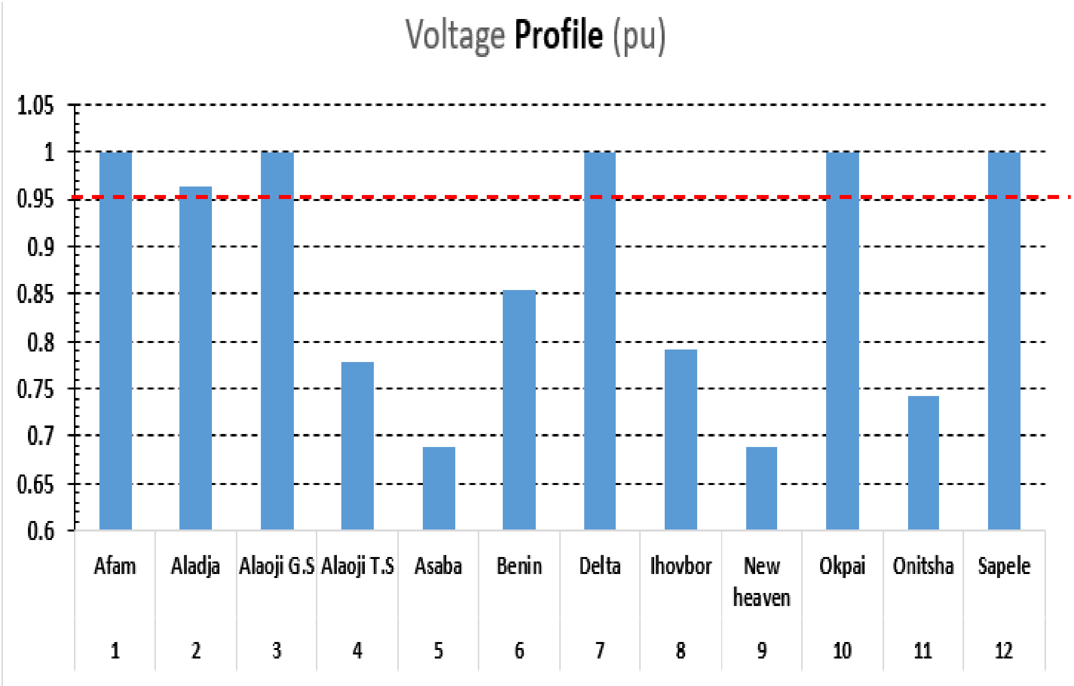

Figure 2 The 12 voltage profile of the 12 buses in the case study power network without the STACOM FACTS Device

Table 1 The active and reactive power transfer dataset for the power network without the STACOM FACTS Device

Line	From Bus	To Bus	Active Power (pu)	Reactive Power (pu)
1	'IHOVBOR'	'BENIN T.S'	0.5561	0.4171
2	'BENIN T.S'	'DELTA G.S'	0.4273	1.2706
3	'ALAOJI T.S'	'ALAOJI G.S'	4.4179	0.0944
4	'ALAOJI T.S'	'AFAM'	0.8498	1.7333
5	'BENIN T.S'	'SAPELE G.S.'	0.4273	1.2706
6	'DELTA G.S'	'ALADJA'	0.4027	0.3259
7	'SAPELE G.S.'	'ALADJA'	0.4027	0.3259
8	'ONITSHA T.S'	'BENIN T.S'	2.1571	0.644
9	'NEW HEAVEN'	'ONITSHA T.S'	0.4201	0.3151
10	'ONITSHA T.S'	'ASABA T.S.'	0.42	0.3727
11	'ONITSHA T.S'	'OKPAI G.S'	0.9666	1.9149
12	ONITSHA T.S'	'ALAOJI T.S'	2.114	0.877

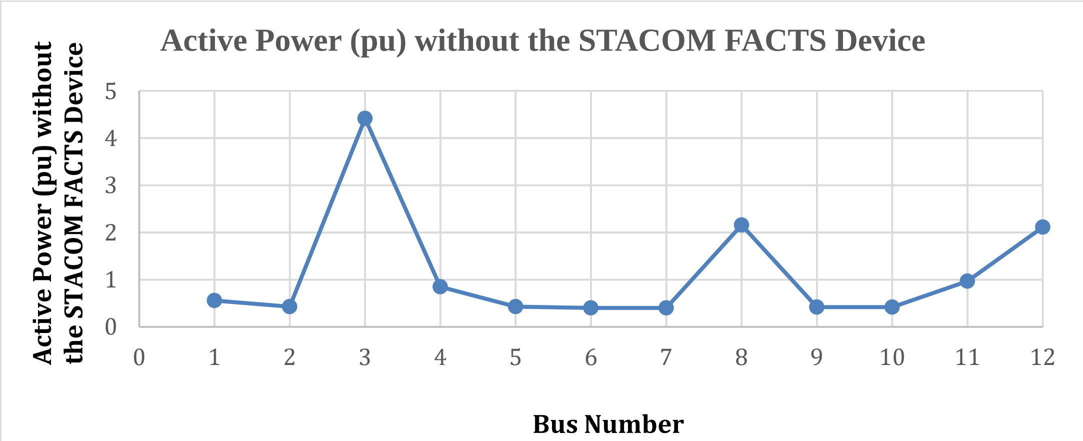

Figure 3 The scatter plot of the active power for the Lines without the STACOM FACTS device

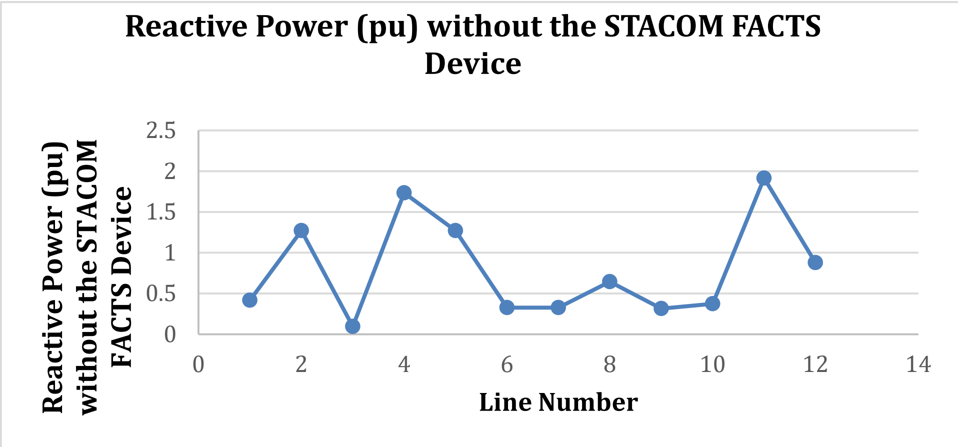

Figure 4 The scatter plot of the reactive power for the Lines without the STACOM FACTS device

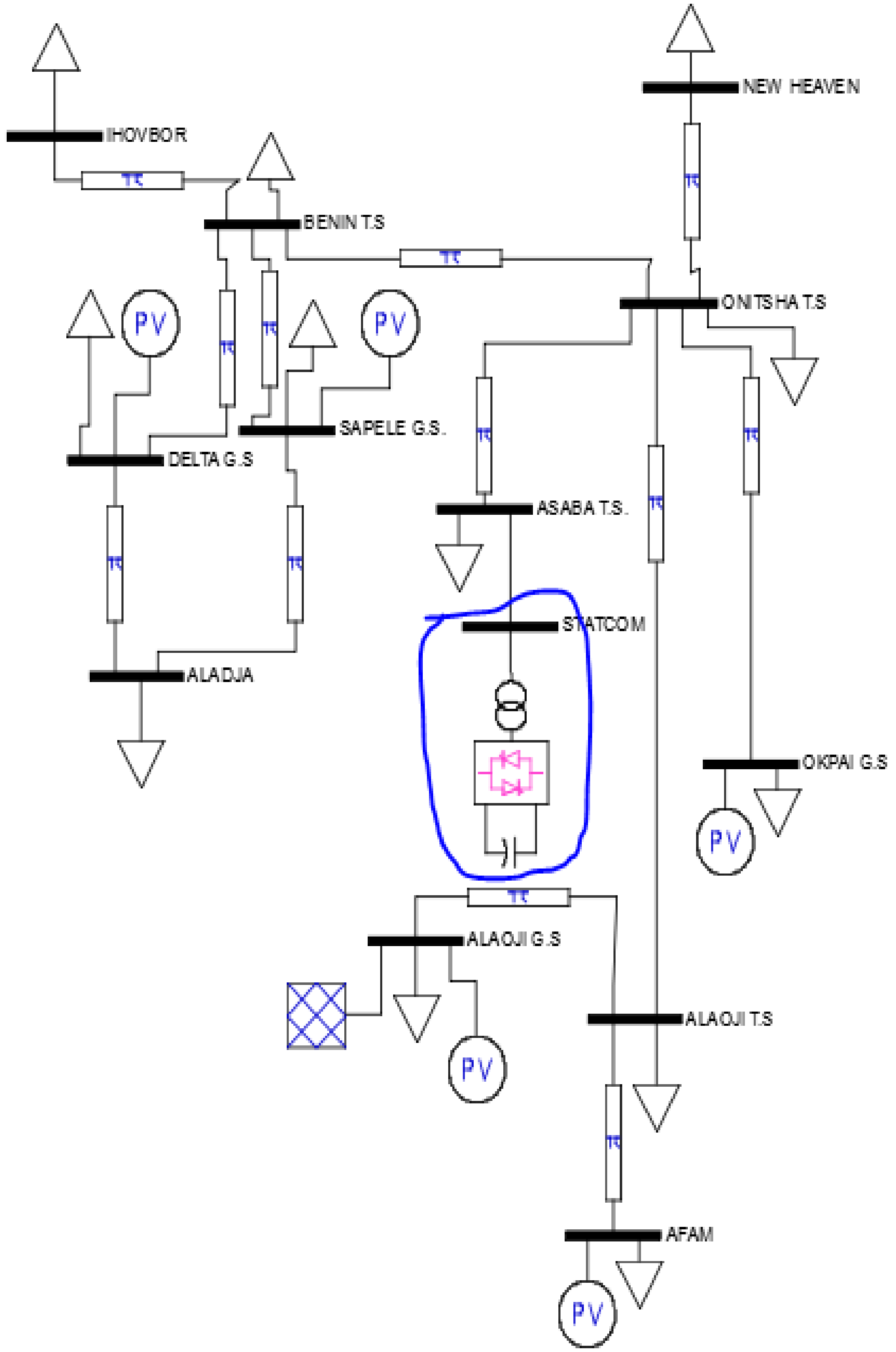

Figure 5 : Power system network with STATCOM

3.0 Results and Discussion

The results of the voltage profile (pu) without StatCom FACTS and with StatCom FACTS are shown in Table 2 and Figure 7 while the accompanying percentage improvements are shown in Table 2 and Figure 7. The STATCOM FACT device gave an average of 12.6 % improvement in the voltage profile of the buses in the power network.

The results of the power transfer capability when StatCom FACTS is not used and also when StatCom FACTS is used are shown in Table 3 , Figure 7 and Figure 8 while the accompanying percentage improvements are shown in Table 3 and Figure 8. The STATCOM FACT device gave an average of 46.4% improvement in the active power transfer in the power network lines and also an average of 42.6% improvement in the reactive power transfer capability of the lines.

Table 2: Voltage profile (pu) without StatCom FACTS and with StatCom FACTS and the accompanying percentage improvements

Bus number	Bus Location	Voltage profile (pu) without STACOM	Voltage profile (pu) with STACOM	Percentage Improvement (%) in Voltage Profile
1	Afam	1	1	0.0
2	Aladja	0.964	0.9644	0.0
3	Alaoji G.S	1	1	0.0
4	Alaoji T.S	0.7773	0.9544	22.8
5	Asaba	0.6884	0.9682	40.6
6	Benin	0.8542	0.9311	9.0
7	Delta	1	1	0.0
8	Ihovbor	0.7921	0.9113	15.0
9	New heaven	0.6884	0.9224	34.0
10	Okpai	1	1	0.0
11	Onitsha	0.7424	0.9599	29.3
12	Sapele	1	1	0.0
			Average	12.6

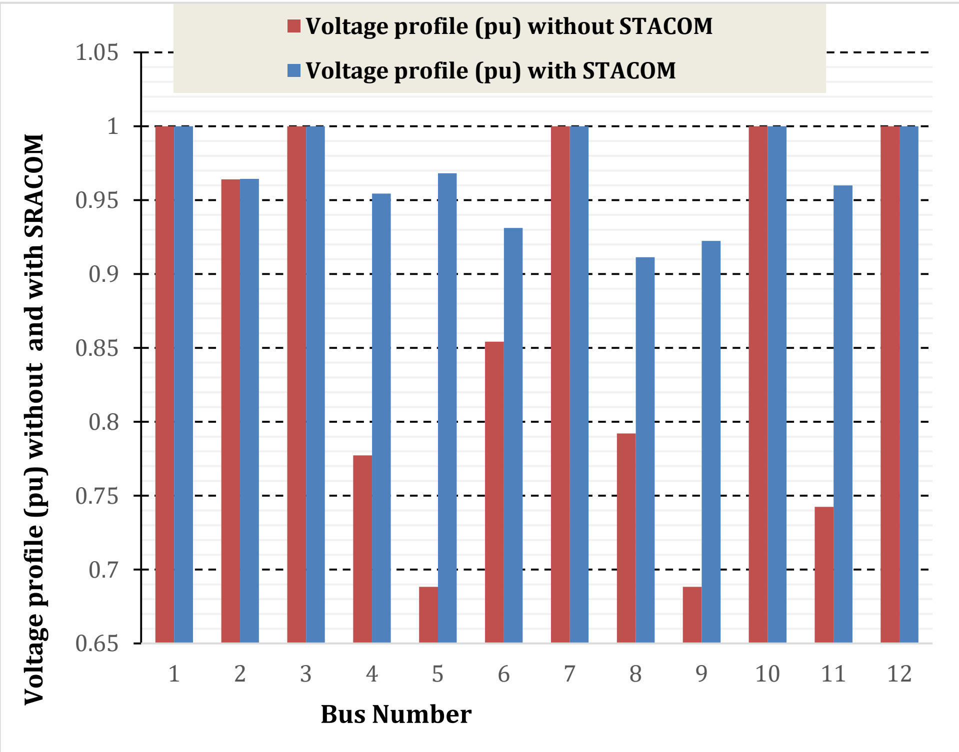

Figure 6 Voltage profile (pu) without StatCom FACTS and with StatCom FACTS

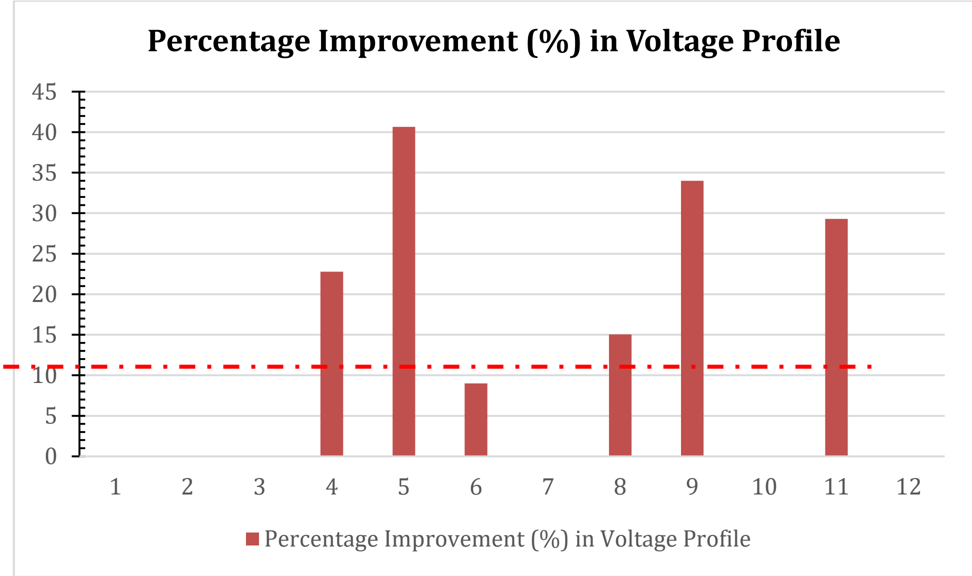

Figure 6 Percentage Improvement (%) in voltage profile due to the introduction of SATCOM FACTS device

Table 3 Power transferred without STATCOM FACTS and with STATCOM FACTS and the accompanying percentage improvements

Line	From Bus	To Bus	Active Power (pu) without STATCOM	Reactive Power (pu) without STATCOM	Active Power (pu) with STATCOM	Reactive Power (pu)with STATCOM	Improvement (%) for Active Power Transfer	Improvement (%) for Reactive Power Transfer
1	'IHOVBOR'	'BENIN T.S'	0.5561	0.4171	0.8723	0.6113	56.9	46.6
2	'BENIN T.S'	'DELTA G.S'	0.4273	1.2706	0.5992	1.3441	40.2	5.8
3	'ALAOJI T.S'	'ALAOJI G.S'	4.4179	0.0944	4.2117	0.2422	-4.7	156.6
4	'ALAOJI T.S'	'AFAM'	0.8498	1.7333	0.9008	1.7133	6.0	-1.2
5	'BENIN T.S'	'SAPELE G.S.'	0.4273	1.2706	0.807	1.4664	88.9	15.4
6	'DELTA G.S'	'ALADJA'	0.4027	0.3259	0.9	0.5196	123.5	59.4
7	'SAPELE G.S.'	'ALADJA'	0.4027	0.3259	0.8331	0.7204	106.9	121.0
8	'ONITSHA T.S'	'BENIN T.S'	2.1571	0.644	2.1014	0.9197	-2.6	42.8
9	'NEW HEAVEN'	'ONITSHA T.S'	0.4201	0.3151	0.5833	0.4152	38.8	31.8
10	'ONITSHA T.S'	'ASABA T.S.'	0.42	0.3727	0.8775	0.5345	108.9	43.4
11	'ONITSHA T.S'	'OKPAI G.S'	0.9666	1.9149	0.9117	1.8921	-5.7	-1.2
12	'ONITSHA T.S'	'ALAOJI T.S'	2.114	0.877	2.114	0.8002	0.0	-8.8
						Average	46.4	42.6

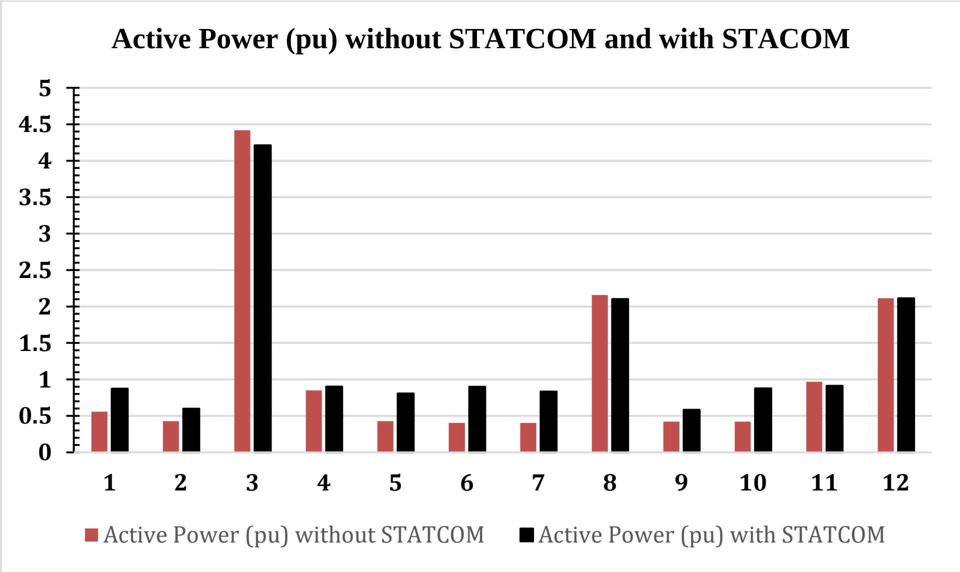

Figure 7 Active power transferred without STATCOM FACTS and with STATCOM FACTS

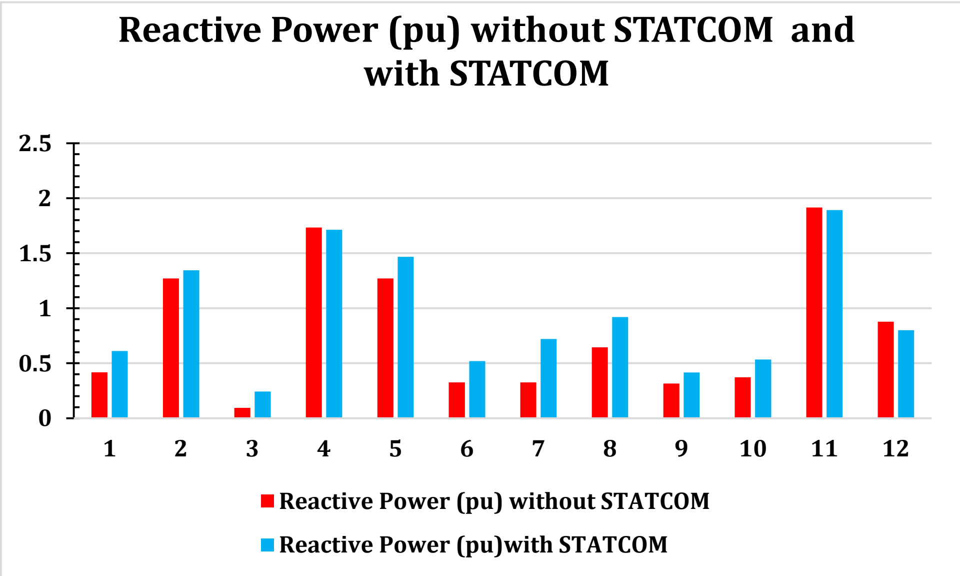

Figure 8 Reactive power transferred without STATCOM FACTS and with STATCOM FACTS

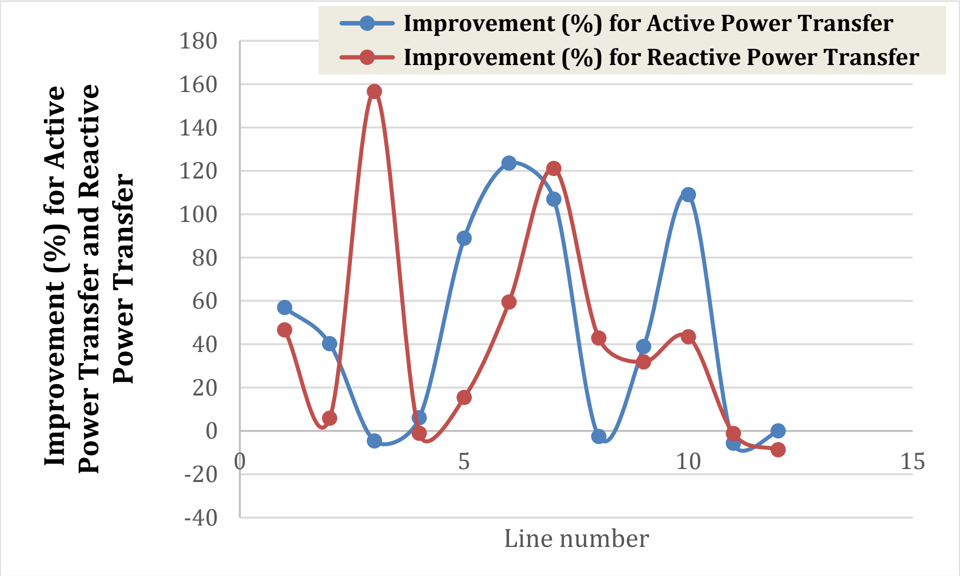

Figure 9 Improvement (%) for Active Power Transfer and Reactive Power Transfer due to the introduction of SATCOM FACTS device

4. Conclusion

The Nigerian 330kV transmission power network is studied with emphasis on the power transfer capability enhancement with A STATic synchronous COMpensator (STATCOM) Flexible AC Transmission Systems (FACTS) device. The selected buses in the transmission power network include Benin, Sapele, Aladja, Delta, Ihovbor, Asaba, Ontisha, Alaoji G.S, Okpai, AlaojiT.S., Afam and New-heaven.

The case study Nigerian 330kV transmission power network buses was modelled on PSAT with STACOM FACTS device connected in order to determine the improvement in voltage profile and power transfer in the studied network due to the use of STACOM FACTS device. Specifically, the simulation analysis of the power network was first conducted without the STACOM FACTS device and then the simulation analysis was conducted with STACOM FACTS device. In all, the use of STATCOM gave about 12 % improvement in voltage profile, about 46% improvement in active power transfer capability and about 42% improvement in reactive power transfer capability.

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