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Improvement of Power Transfer Capability of Nigeria National Grid with TCSC FACTS Controller

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ABSTRACT : *The Nigeria power transmission network has constantly recorded increase in demand to increase in power flow congestion leading to drastic reduction in power transfer capability in transmission and distribution lines. This issues led to determination of methods and avenues of improving the power flow which resulted to the improvement of the available transfer capability (ATC). In this paper, the Nigerian 330kV transmission network was modeled using NEPLAN software.Thyristor controlled series capacitor (TCSC) FACTS device was deployed to improve the power flow and the available transfer capability. The Optimal location for the implementation of the FACTS device was determined usingGenetic Algorithm (GA) optimization technique based on the linear regression relationship between the available transfer capability and the summation of the transmission line distance. Comparative analysis was performed between the modeled power system network without FACTS and the power system network with TCSC. From the results presented, the outcome of optimum location identified by GA was ATC of 74.31MW at summative distance of 954.5km.The optimum distance was line 8 between Benin TS and Oshogbo TS. Hence the TCSC FACTS was placed at the transmission line connecting Benin and oshogbo. The simulated results also showed that without TCSC FACTS device, ATC on buses 2,7,8,12,16,17,26, and 28 were well below 80 MW with the highest of 87 MW recorded at bus 10. With the introduction of TCSC, the ATC at all the buses improved to between 85 MW and 92 MW.*

KEYWORDS *Available transfer capability, FACTS, optimal location, TCSC, Transmission line.*

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I. INTRODUCTION

In the field of electric energy, the role of the electric network is crucial and access to a reliable electricity supply plays a pivotal role in empowering individuals and facilitating personal and economic development as the economic growth and development of any nation are intrinsically tied to the availability of energy [1,2,3]. The available transfer capability has been a factor used to determine the amount of power that is transmitted to load stations from generation stations [4]. In the Nigeria power system studied by [5,6], it was found that the constant epileptic power supply constantly recorded in power transmission systems in Nigeria was largely due to rise in power congestion in the power flow in the transmission and distribution lines. The reduction in available transfer capability also affected the durability, stability, economic stability and power transmission stability of the transmission power systems in Nigeria [8].

In curbing the issues, this paper proposed the use of series FACTS device in the improvement of the available transfer capability (ATC) of the power system network. The improvement of the ATC would reduce the rate of epileptic power supplied and improve on the existing power congestion in the Nigerian power transmitted and distributed. However, several procedures were required in the improvement of the ATC of which the most essential was the optimal FACTS placement determination [9] with particle swarm optimization technique which involved development of relationship between the distance and the ATC. The data utilized in this paper will be a real time network obtained from the Nigeria Control center (NCC) Oshogbo. The power system network will be modeled in NEPLAN with the power flow analysis performed and obtained and the same will be done for the ATC. The TCSC FACTS controller will be placed according to the optimal location obtained from the Genetic Algorithm performed. The power flow analysis and the ATC for the system with and without FACTS will be analyzed and compared to display improvement of the ATC through the reduction of the power congestion on the transmission lines.

II. REVIEW OF RELATED LITERATURE

The IEEE 30 bus network model base on different TCSC placement methods which included line reactance, power transfer distribution factor, line thermal limitation and least bus voltage magnitude was carried out in [4] to determine the ATC.The outcome gave an ATC increment between 2% to 85% at various placement methods and real power loss reduction achieved was up to 25%. Also, in the determination of the ATC with FACTS devices carried out using the power loss sensitivity index method and continuation power flow for the optimal location of FACTS devices,the combination of Thyristor controlled series capacitor (TCSC), Unified power flow controller (UPFC), and interline power flow controller (IPFC) were employed.The simulation was done in the Nigerian 58 bus system modeled in NEPLAN and IEEE-9bus network in powerworld 8.0. The study showed an appreciable ATC improvement with the installation of the FACTS controllers [5,6]. In the application of flexible alternating current transmission system (FACTS) to enhance transient stability using the Nigerian 48-bus power system network in [7], two different FACTS devices were deployed namely SVC and STATCOM. PSAT, a commercially available power system analysis toolbox in MATLAB was used to model the Nigerian power system network with simulated fault introduced at Geregu substation located at bus 33 and the two FACTS devices separately placed at bus 21(Jos transmission station. The outcome showed a high level of stability on voltage and power.The optimal enhancement of ATC improvement of the IEEE 30 bus network using TCSC to determine the optimal location of the TCSC in the power system network using GA optimization tool was discussed in [8].The study was described as the new approach. The outcome showed an improvement on ATC with the installation of TCSC. The study to determine the ATC of an IEEE 30 bus power system network with IPFC using the particle swarm optimization (PSO) to obtain the optimal IPFC settings was carried out in [10,11]. MATLAB version 7.10. 0 was deployed to run the simulation and the outcome showed a good improvement of ATC with the introduction of IPFC. Boosting of ATC in IEEE 30 bus and 6 bus sample using the PSO tool on the optimal settings of the TCSC for the enhancement of the ATC of the network was studied in [12]. The outcome showed an increment in ATC in the power system network. In the steady state application of multitypes FACTS controllers, the authors in [13] employed TCSC and static VAR compensator (SVC) in the 48 bus system of Nigeria using voltage stability sensitivity factor for the enhancement of voltage profile and the reduction of active and reactive power loses in the system. [14] carried out the the study to determine ATC on transmission lines to improve the outcome using TCSC on an IEEE 24-bus network. The ATC was determined with repeated power flow (RPF). the paper failed to carry out optimal FACTS placement of the TCSC with any optimal tool. Another study carried out in [15]used PSO in the estimation of the optimal settings of TCSC device for the enhancement of ATC on power system network. Simulated results showed the effective improvement in the ATC of the power system. The study in [16,17], deployed SVC and TCSC FACTS model into the Newton Raphson power flow analysis model and simulated the model with IEEE 30 bus network in Matlab. 14% ATC improvement were recorded for both the SVC and the TCSC devices. The gap in this study was the absence of optimal location placement of the FACTS.The optimal placement and sizing of TCSC was studied in [18]using GA optimization tool. The author used power transfer distribution factor for the determination of the ATC and was compared to the ATC calculated from repeated power flows method. The outcome showed that the use of power transfer computation factor was more reliable in determining the ATC of power system network than the repeated power flow method. This study centered more on the format of calculating ATC and not on improvement of ATC with the FACTS which was the major gap of the research. In transient stability studies, the authors in [19,20,21] optimally positioned SSSC and TCSC in the Nigerian 48 bus system using continuation power flow and validated using voltage stability sensitivity factor. The system was modeled using the commercially available power system analysis toolbox (PSAT) and simulated under application of a three phase fault and line outages. The results displayed effective damping of power system oscillation and improvement of voltage profile of the system. Likewise in the studies on ATC enhancement in a 4-bus system network using cascaded based ANN model with SSSC FACTS was carried out in [22], it was used to stabilize the constant rise in independent operator system (ISO) and MatLab was used for the simulation. The gap to this study was the absent of optimization tool for the optimal placement of the SSSC FACTS. The study in[23]reviewed several ways of determining ATC and other parameters of Power transfer capability and how the ATC can be improved with FACTS in a 14-bus network which the outcome showed that ATC of the power system network was improved. There was absence of optimal placement of the FACTS for further improvement of the ATC in the 14-bus network. The authors in[24]compared the outcome of ATC improvement with SSSC and UPFC and also determined the TTC with both FACTS in a 30-bus network. The model was simulated with power system analytical tool and the outcome showed an improved ATC with both FACTS. The gap in this study was the absence of optimal FACTS location with any optimal tool.

III. MATERIALS AND METHOD

The data utilized in this work is obtained from the National control center in Oshogbo, Osun State, Nigeria. The data comprises of line diagram of Nigerian 330kV transmission network of Southern region comprising of 28 buses.The snapshot of the power system diagram involving the buses and the transmission lines are presented in Fig. 1.

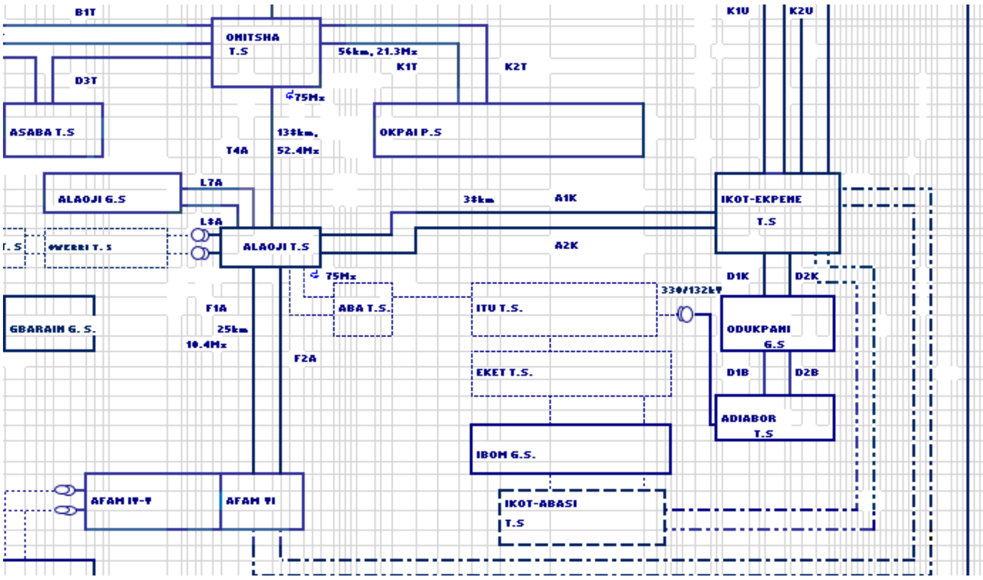

Fig.1. Southern region of the Nigerian 330kV transmission network

The power system real time data of the network shown in Fig.1 comprises of 28 buses and 36 transmission lines. The area was mainly 330kV network that spans from the south western region, south southern region and south eastern region. The NEPLAN model of the network is shown in Fig.2.

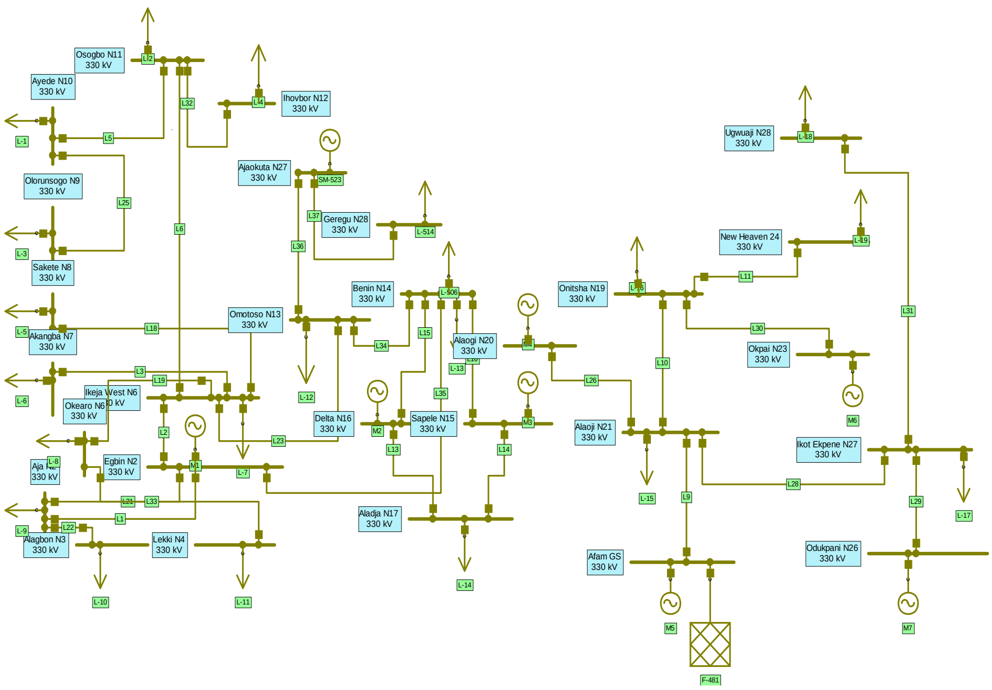

Fig.2. NEPLAN model of the power system network without FACTS

The regression model schematics showing the relationship between the available transfer capability and the distance of the transmission line as obtained from the simulation of the power system model ofFig.2 is given inEquation 1.

$$ATC = \sum_{i=0}^{n} a_{i} D_i^n \qquad (1)$$

Where D is the distance in km, a represents the coefficient of the distance that is determined using least squared method in MATLAB. The simulation of the power system network without FACTS in Fig.2 generated the power flow values and the ATC at various distances utilized in the formation of the regression model that is subjected to genetic algorithm to determine the optimum distance.

From the ATC and distance values obtained from the power system model in Fig.2, the values were sent to MATLAB where the polynomial order was adjusted until an order at error (E) of 0.0001 or less was obtained with the model subjected to genetic algorithm to obtain the optimaldistance for FACTS placement. The NEPLAN Model with TCSC is shown in Fig.3.

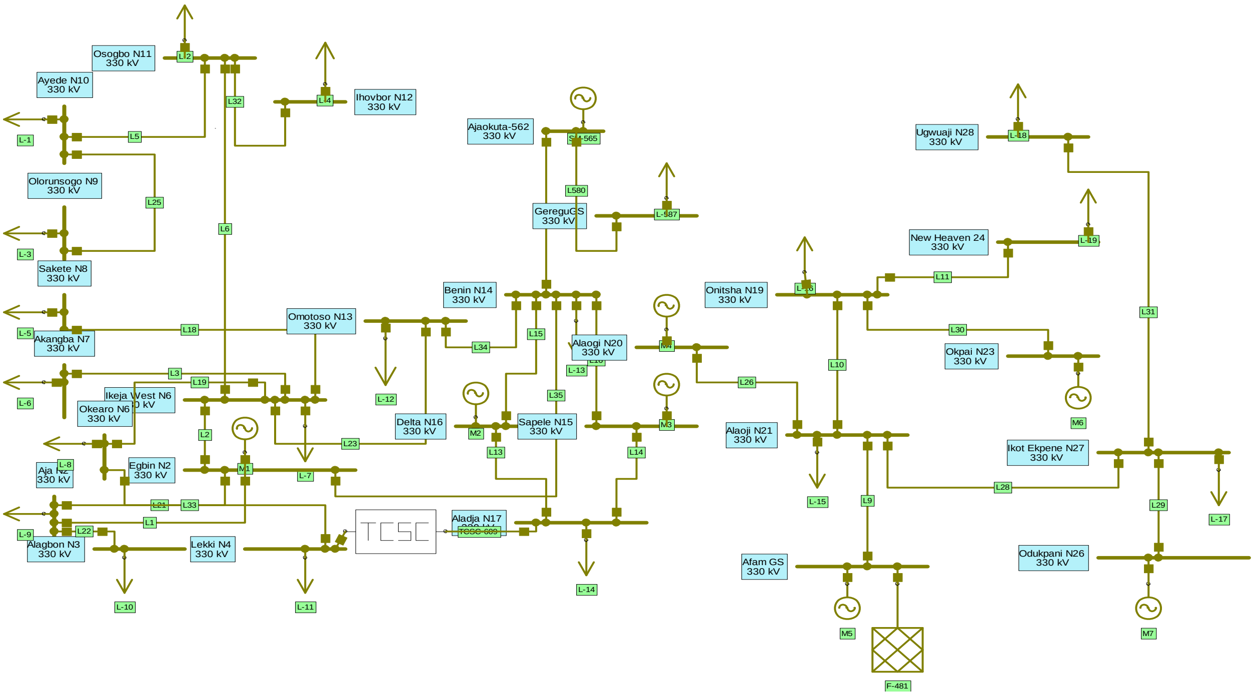

Fig.3. Power system model with TCSC in NEPLAN

IV. RESULTS AND DISCUSSION

The snapshot of the MATLAB tool deployed for the determination of the regression polynomial for the determination of the relationship between available transfer capability and the line distance is shown in Fig.4 and the data utilized for the fitting of the model is as shown in Table 1.

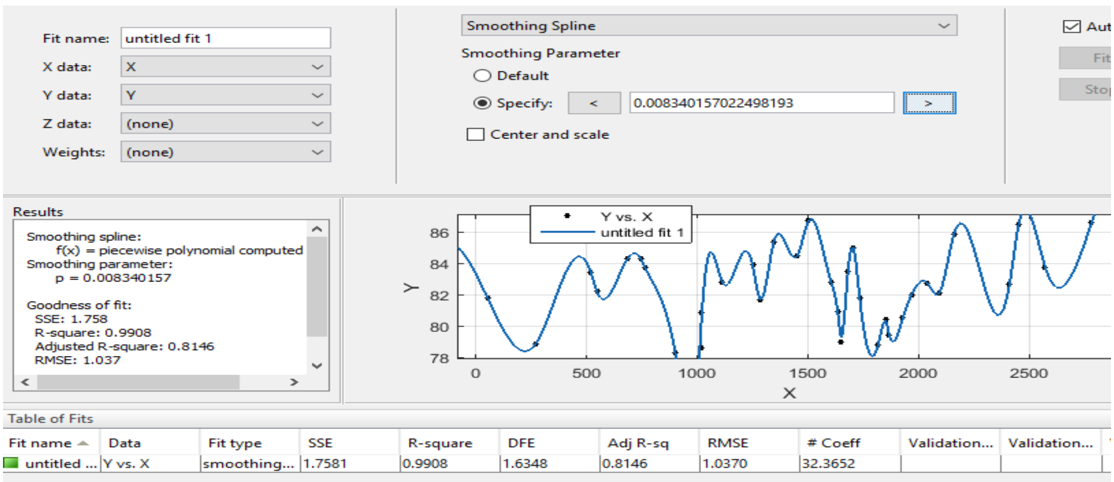

Fig.4. Model for the fitting of line distance and ATC value of the southern Nigerian 330kV network in MATLAB

Table 1. Data utilized for fitting

Transmission line distance (kM)	ATC (MW)
270	78.8481
521	83.3867
546	82.2383
684	84.2635
746	84.2990
764	83.7468
901	78.3024
1016	78.6193
1018	80.8764
1114	82.7778
1251	83.8900
1283	81.6686
1346	85.3798
1453	84.4652
1503	86.7178
1605	82.7820
1637	80.9263
1651	78.9507
1681	83.4986
1707	85.0092
1734	81.8111
1819	78.8174
1854	80.3982
1867	79.3829
1930	80.5290
1968	81.9608
2040	82.7443
2096	82.1168
2161	85.8783
2412	82.6625
2453	86.4926
2573	83.7394
2783	86.6192

The best fitted model outcome had an error (E) value of 0.000087 at prediction accuracy of 99.08%. The model was subjected to genetic algorithm and the optimal outcome obtained was ATC of 74.31MW at distance of 954.5km.The optimum distance was line 8 between Benin TS and Oshogbo TS. Hence, the TCSC FACTS controller was placed at the transmission line connecting Benin and Oshogbo. The ATC of the power system without FACTS is displayed in Fig.5.

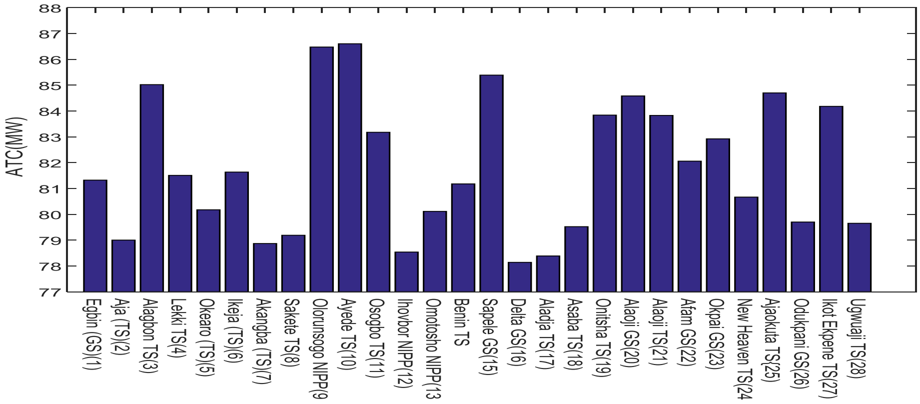

Fig.5. ATC without FACTS in the Southern Nigerian 330kV power system network.

From the barchart of Fig.5, it is observed that the ATCs were low in buses 2,7,8, 12, 16, 17, 26, and 28. This suggest power congestion and a means of power transfer improvement was needed to improve the ATC of the network to ensure maximum transfer of power from one point to another within the network. The outcome of ATC with TCSC FACTS deviceis plotted and displayed in Fig.6.From Fig.6, it is observed that there is an ATC improvement with the installation of TCSCFACTS device when compared to the ATC outcome of the system without FACTS. Fig.7 shows the comparative bar chart of the ATC without and with TCSC.

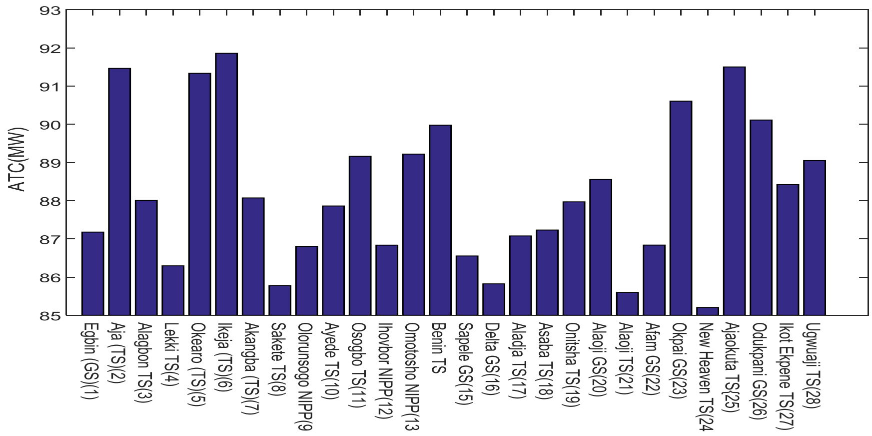

Fig.6. ATC with TCSC FACTS in the Southern Nigerian 330kV power system network

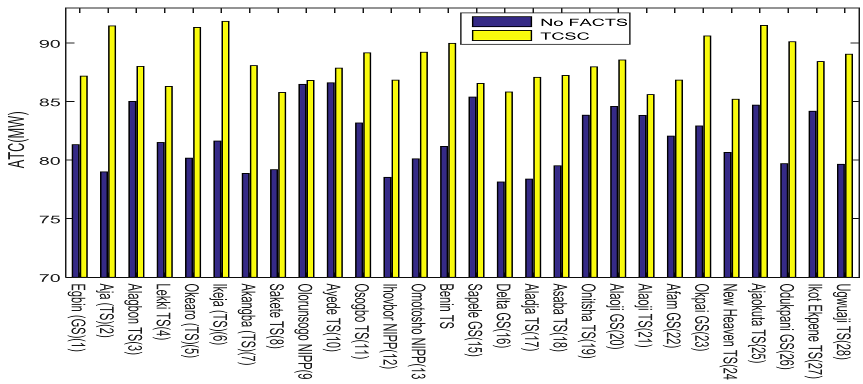

Fig.7. Comparative analysis of the ATC for with and without TCSC FACTS controllers

V. CONCLUSION

The major aim in this study was to obtain the optimum placement of TCSC FACTS controller for the improvement of the available transfer capability (ATC) of the southern region of the Nigerian 330kV transmission network. The power system network was modeled and the power outcome obtain from NEPLAN software. Genetic algorithm was used to optimize the obtained polynomial relationship between the ATCs and the transmission line distance. The outcome of the optimum location identified by genetic algorithm was ATC of 74.31MW at summative distance of 954.5km.The optimum distance was line 8 between Benin TS and Oshogbo TS. Hence, the TCSC FACTS was placed at the transmission line connecting Benin and Oshogbo. The ATC of the power system without and with TCSC FACTS controller was obtained and presented. The outcome showed that with application of TCSC, the ATC was effectively improved thereby minimizing the rate of power congestion in the power system.

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