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# Steady-State Stability Improvement with Incorporation of SVC and Additional Transmission Line Using Synchronous Power Coefficient.

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**Abstract- Every power system comprises many generators that are connected in parallel. For the system to operate in steady-state stability, all the generators must run synchronously. If any of the connected generators loses synchronism, system stability is lost, and voltage collapse may occur. To avoid this situation, steady-state stability (SSS), which involves voltage stability and synchronisation of generators, must be monitored. This paper, therefore, focuses on the SSS using the 6-bus IEEE test network and the Nigerian 30-bus, 330 kV grid network as case studies. Power-flow analysis was carried out for the case studies. Static var compensator (SVC) and additional parallel transmission lines were used to carry out voltage improvement for each network. The use of SVC for both IEEE and Nigerian networks indicates better voltage compensation than using transmission line enhancement, but the reverse is true for power loss reduction. The power losses in the 6-bus IEEE for original and improved networks with SVC and additional transmission lines are 1.8 %, 1.6 %. and 1.2 % respectively. At the same time, those of the Nigerian 30-bus, 330 kV network are 4.3%, 3.7%, 3.10%, respectively. Synchronous Power Coefficient (SPC) was used to carry out SSS by considering load additions in steps of 20% to the original and modified networks. SSS of the modified network with SVC and the original network were approximately the same. In contrast, the SSS was improved for the networks modified with additional transmission lines. Since SSS depends on the system inertia during load variation, the inertia of the network modified with the transmission lines is improved, while SVC does not exhibit noticeable inertia properties.**

**Keywords- System inertial, Droop curve, Synchronous power coefficient, SVC, Power transfer distribution factor.**

## I. INTRODUCTION

Power systems are complex artificial infrastructures that require multiple controls for satisfactory operation. The SSS of power system is determined by permissible control of frequency (±1%) and voltage (±5%) [1]. Changes in load may cause deviation from these requirements. One of the objectives of control in power system operation is to obtain a reliable supply of electric power at a statutory quality by taking suitable measures against various load changes. There are constantly varying small quantity changes in the load of the systems. The adverse effect of load variation otherwise described as disturbance can be mitigated by implementing regulatory controls, such as governors and exciters [2]. Large-scale disturbances occur due to sudden or significant magnitude changes in system operating conditions, such as faults on the transmission network, tripping of a large generating unit or sudden connection or removal of large blocks of loads [5]. Large-scale disturbances caused by disconnecting blocks of loads can be mitigated by proper planning and the adoption of emergency switching control [6].

The development of a power system begins with the generation of electrical power by a synchronous generator, which is then transmitted at high voltage and finally distributed to consumers. This indicates that the synchronous generator plays a vital role in power system operation and should not be allowed to malfunction [3]. A synchronous generator comprises both mechanical and electrical parts. The prime mover provides relative motion between the stator and rotor windings to generate electrical power at a statutory frequency and voltage. Hence, the mechanical speed of the prime mover and the frequency of power supply generated must obey a statutory relationship. In this study, the Synchronous Power Coefficient (SPC) is considered for frequency control in power systems. SPC is the change in real power generated by any synchronous generator to the change in rotor angle whenever there is a change in the active load connected to the system [4]. Whenever changes in the load occur, it will take the machine a finite amount of time (known as the dead band) to adjust its output in response to the disturbance [9]. When a load is added to the system, the governor adjusts its setting to increase the valve opening and supply more fuel . During this time, the generator has not increased its output. The inertia of the system sustains the operation of the machine [5]. The generation and load must always be maintained in power system operation, and this condition is described as steady-state stability [6].

For SSS to be achieved, the governor's action should be completed and adjust its output provided the total load is not more than its rated capacity. The condition in which the generator operates at its rated capacity while SSS is maintained is described as the SSS limit [6]. Any load greater than the rated capacity of the generator would make the system inertia, and the governor action fails to complete its cycles, and such a generator would shut down. If this is not adequately controlled, it would lead to voltage collapse and eventual system failure.

To avoid this catastrophic condition, the system's inertia must be able to cope with the load addition within the dead band of the synchronised generators. The objective of this article is to carry out SSS improvement by enhancing voltage stability to reduce power loss and thereby improve system inertia. Since SSS involves both voltage and frequency control, voltage enhancement is achieved using SVC and additional parallel transmission lines to the topologically weak transmission lines. Topologically weak transmission lines were determined using the power transfer distribution factor (PTDF) [8]. After normalising all the bus voltages, SPC was performed for each modified network to evaluate SSS.

Several research works have been presented in the literature of power system analysis. The authors in [9] employed changes in the waveform due to gradual changes in load using a MATLAB/Simulink model. The method further proposes the use of a Power System Stabiliser system (PSS) to improve the network. Eigenvalues are calculated and are used to determine the stability of the system. PSS reduces the oscillation of the rotor angle of the generator and thereby controls the frequency within the statutory value and eventually improves the SSS. But PSS has a complex process and requires expertise and specialised knowledge.

The research work reported in [4] is based on SSS using SPC with MATLAB software used as the simulation tool for the Nigerian 330kV, 30-bus network. Positive values of SPC indicate stability, and negative values indicate otherwise. However, the author did not perform voltage magnitude stability improvement before determining SSS.

The research in [8], as presented by the authors, performed transmission expansion for the Nigerian 330 kV, 30-bus network. The authors determined six topologically weak transmission lines using the power transfer distribution factor (PTDF) in the NEPLAN application software. The weak transmission lines were reinforced to expand the transmission network. Only voltage stability improvement was considered in the research.

The study presented in [10] assessed the optimal placement of SVC on low-voltage buses using a genetic algorithm (GA) for the Nigerian 28-bus power system. The simulation was conducted in the MATLAB 2020a environment. The authors in [10] developed a reactive power control technique for generator synchronisation using the Nigerian 30-bus power network. The authors in their study control the power factor, which does not affect the active power flow, allowing all generators to remain in synchronism. The study investigated power factor control for system synchronisation.

The analysis used in this paper considers both voltage and frequency controls. These are carried out to ensure the necessary and sufficient conditions are met for SSS. Voltage stability improvement was carried out using SVC and additional transmission lines, while SPC was used for frequency control. The merit of this study is to investigate the combined effect of voltage and frequency on power system analysis. This paper is structured as follows: Section 1 presents the introduction to the article, Section 2 outlines the materials and methods, while Section 3 describes the case studies considered, which include the IEEE 6-bus system and the Nigerian 330 kV, 30-bus system. The conclusion is presented in Section .

## II. MATERIALS AND METHODS

**Power Flow Equations**

The power flow equations are given by (1) and (2) for active and reactive powers, respectively .

$$P_i = \sum_{j=1}^{y} |V_i||V_j||Y_{ij}| cos(\delta_j - \delta_i + \theta_{ij})$$

$$Q_i = -\sum^{y}{}_{j=1} |V_i||V_j||Y_{ij}| sin(\delta_j - \delta_i + \theta_{ij})$$

wherei □1, 2, ...,n, and j= 1,2,3……y

$\delta$ is the rotor angle, $|V|$ is the voltage magnitude, $|Yik|$ is the admittance matrix and $\theta ik$ .is the load angle.

**Modeling of SVC**

Figure 1 shows that one branch of the SVC is purely inductive while the other branch is strictly capacitive. It either consumes reactive power (inductive) to reduce the system's voltage or injects reactive power (capacitive) to increase the system's voltage.

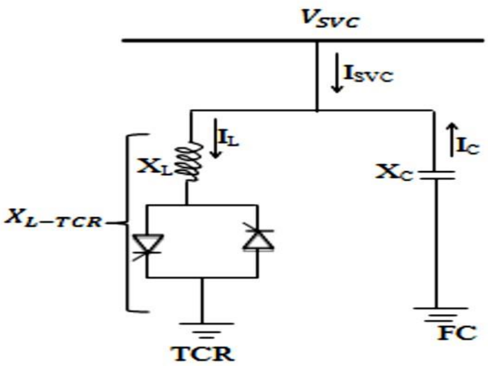


**Figure 1**: Functional diagram of a SVC

After connecting SVC to the buses that are experiencing low voltage, (1) and (2) are modified and rewritten as (3) and (4) respectively.

$$P_i = \sqrt{\frac{Q_{SVC} X_L X_C}{X_C - X_L}} \sum_{k=1}^{n} Y_{ik} V_k \cos(\theta_{ik} + \delta_k - \delta_i) \quad (3)$$

$$Q_i = -\sqrt{\frac{Q_{SVC} X_L X_C}{X_C - X_L}}) \sum_{k=1}^{n} Y_{ik} V_k \sin(\theta_{ik} + \delta_k - \delta_i) \quad (4)$$

$X_C$ is the Capacitive reactance of the SVC; $X_L$ is the Inductive reactance of the SVC; C is the Capacitance of the fixed capacitance of the SVC; f is the Frequency of the system, and $V_{SVC}$ is the Bus Voltage magnitude.

**Modelling of Power Transfer Distribution Factor (PTDF)**

$$\Delta P_{lm} = \left[ \frac{\partial P_{lm}}{\partial \delta_2}, \ldots\ldots, \frac{\partial P_{lm}}{\partial \delta_n} \frac{\partial P_{lm}}{\partial V_{g+1}}, \ldots\ldots, \frac{\partial P_{lm}}{\partial V_n} \right] [J^{-1}] \begin{bmatrix} 0 \\ : \\ +P_t \\ 0 \\ : \\ -P_t \\ 0 \end{bmatrix} = d_t P_t \quad (5)$$

In order to determine the sensitivities of variation in load to variation in generated output for synchronous generator and hence, determine topologically weak transmission lines, PTDF index as given in (5) is employed. Where dt is the (PTDF), k is the Generator bus (source), is the Load bus (sink), l-m is the transmission line (from l to m), ΔPl-m is the change in power flow on transmission line l-m , Pki is the generated power, and J is the load flow Jacobian. To improve the voltage magnitude of the buses that experience low voltages,additional transmission lines are connected in parallel, aiding the topologically weak transmission lines.

**Modelling of Synchronous Power Coefficient (SPC).**

SSS is asses by SPC. Since SPC is a measure of change in the output power of the generator due to the change in loadangle on the system. The power system network is therefore reduced to a generator-generator using the matrix reduction method. The reduced matrix is given in .

$$Y_{RED} = [Y_{AA} - Y_{BA} Y_{DD}^{-1} Y_{DC}] \quad (6)$$

Where $YAA$ is (generator-generator buses), $YBA$ is (generator-load buses), $YDC$ is (load-generator buses) and $YDD$ is (load-load buses). As the load on the system changes, the rotor angle of the generator would change. The load angle is proportional to the rotor angle. Therefore, SPC, given by would change. Change in rotor angle is proportional to change in system frequency. Hence, SPC is a measure of variation of frequency.

## III. RESULTS AND DISCUSSION

Results and discussion of the two case studies are provided in this section. The case studies are the IEEE 6-bus and Nigerian 30-bus, 330 kV networks.

Results of Power Flow and SPC for Original and Modified IEEE 6-Bus Network

Power flow is shown in Table 1. All the buses are within the statutory limit. Buses 4 and 5 were improved to 1.0 p.u by the incorporation of an SVC. The power flow of the modified network is also shown in Table 1. Power loss is improved from 3.93 MW to 2.62 MW after modification. Three transmission lines were identified to be topologically weak using PTDF. The network was enhanced by adding Parallel transmission lines to the weak transmission lines. The network was modified by adding parallel lines with the topologically weak lines. The results of the improved power flow are shown in Table 2. The power loss (2.61 MW) was smaller than the one modified by the SVC.

The results show that SVC improves the system voltage better than using transmission lines. The load on the system was increased by 20% for both the original and each modified network, and SPC was carried out to detect SSS. The SPC results are contained in Table 3. The results show that the SPC for the original network and the SVC modified network are the same, but improved for the network with additional transmission lines.

Table 1: Power Flow Results for the 6-Bus IEEE Netwok

| Power Flow Results with the Original Load | | Power Flow Results with the Original Load plus SVC | |
|---|---|---|---|
| Bus no | ***value P. U\|V\|***(P.U) | Bus no | ***value P. U\|V\|***(P.U) |
| 1 | 1.05 | 1 | 1.05 |
| 2 | 1.05 | 2 | 1.05 |
| 3 | 1.07 | 3 | 1.07 |
| 4 | 9.89 | 4 | 1.00 |

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| | | | |
|---|---|---|---|
| 5 | 9.85 | 5 | 1.00 |
| 6 | 1.01 | 6 | 1.48 |

Table 2: Power Flow Results for the 6-Bus IEEE Network

| Power Flow Results with the Original Load plus Transmission Lines | |
|---|---|
| Bus no | $\boldsymbol{value\ P.U}\|\boldsymbol{V}\|$(P.U) |
| 1 | 1.05 |
| 2 | 1.05 |
| 3 | 1.07 |
| 4 | 1.02 |
| 5 | 9.96 |
| 6 | 1.03 |

Table 3: Synchronous Power Coefficients (SPC) for the 6-Bus IEEE Network

| SPC with the Original load | | SPC with the Original load and SVC | | SPC with the Original Load and Transmission Lines | |
|---|---|---|---|---|---|
| 2.4763 | 3.1101 | 2.4764 | 3.1120 | 2.5760 | 3.2103 |
| 2.4763 | 1.5857 | 2.4764 | 1.5858 | 2.5760 | 1.6857 |
| 3.1101 | 1.5857 | 3.1120 | 1.5858 | 3.2103 | 1.6857 |

**Results of Power Flow and SPC for Original and Modified 330 kV, 30-Bus Nigeria Network.**

Similar analysis of the study for case 1 is repeated for the Nigerian 30-bus network. The results for the original power flow are shown in Table 4. The power loss was 219.08 MW. Six buses experienced low voltage magnitude and were improved by using SVC. The results are displayed in Table 5. The power loss was reduced to 185.46 MW. Six transmission lines were discovered to be topologically weak. Network improvements were performed with the addition of parallel transmission lines. Tables 6 illustrates the improvement in voltage stability achieved through the use of transmission lines. The power loss was further reduced to 156.70 MW. Tables 7, 8 and 9 show power flow results when the load on the network is increased by 20% for original, SVC and additional transmission lines respectively. while Tables 10, 11 and 12 show the SPC results when the loads were increased by 20% for original, improved network with SVC and transmission respectively. It is discovered that the SSS is improved with the addition of parallel transmission lines, while the SSS of the SVC-modified network is the same as that of the original network.
The inertia of the network modified with the transmission lines, while the SVC does not have noticeable inertia.

Table 4: Power Flow Results with the Original Load.

| Bus no | $\|\boldsymbol{V}\|$(P.U) | Bus no | $\|\boldsymbol{V}\|$(P.U) | NO BUS OF | $\|\boldsymbol{V}\|$(P.U) | NO OF BUS | $\|\boldsymbol{V}\|$(P.U) | NO OF BUS | $\|\boldsymbol{V}\|$(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 1.01 | 18 | 1.02 | 24 | 0.81 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.04 | 20 | 0.95 | 26 | 0.81 |
| 4 | 1.05 | 10 | 1.04 | 16 | 1.00 | 22 | 0.66 | 28 | 1.02 |
| 5 | 1.05 | 11 | 1.01 | 17 | 1.03 | 23 | 1.04 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.04 | 19 | 0.90 | 25 | 0.96 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1.05 | 9 | 1.05 | 15 | 1.03 | 21 | 0.98 | 27 | 0.93 |

The power flow results in Table 1 show that six buses have their voltage magnitude outside the voltage statutory limit of 1±0.05. SVC was used to improve the voltage magnitude of all the buses and the improve power flow results are indicated in Table 6. Table 5: Power Flow Results with the Original Load and SVC

Table 5: Power Flow Results with the Original Load and SVC

| NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 1.01 | 18 | 1.02 | 24 | 1.00 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.04 | 20 | 1.00 | 26 | 1.00 |
| 4 | 1.05 | 10 | 1.04 | 16 | 1.00 | 22 | 1.00 | 28 | 1.03 |
| 5 | 1.05 | 11 | 1.01 | 17 | 1.03 | 23 | 1.04 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.04 | 19 | 1.00 | 25 | 1.02 |
| 3 | 1.05 | 9 | 1.05 | 15 | 1.04 | 21 | 0.98 | 27 | 1.00 |

Table 6: Power Flow Results with the Original Load and Additional Transmission Lines.

| NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 1.02 | 18 | 1.03 | 24 | 0.99 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.04 | 20 | 0.99 | 26 | 0.96 |
| 4 | 1.05 | 10 | 1.04 | 16 | 1.00 | 22 | 0.97 | 28 | 1.03 |
| 5 | 1.05 | 11 | 1.01 | 17 | 1.03 | 23 | 1.05 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.04 | 19 | 0.97 | 25 | 1.01 |
| 3 | 1.05 | 9 | 1.05 | 15 | 1.03 | 21 | 0.98 | 27 | 1.02 |

Table 7: Power Flow Results With 120% of the Original Load.

| NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P. U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 0.99 | 18 | 1.00 | 24 | 0.79 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.02 | 20 | 0.94 | 26 | 0.79 |
| 4 | 1.05 | 10 | 1.02 | 16 | 0.98 | 22 | 0.65 | 28 | 1.01 |
| 5 | 1.05 | 11 | 0.99 | 17 | 1.01 | 23 | 1.02 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.02 | 19 | 0.89 | 25 | 0.94 |
| 3 | 1.05 | 9 | 1.05 | 15 | 1.01 | 21 | 0.95 | 27 | 0.91 |

Table 8: Power Flow Results With 120% of the Original Load and SVC

| NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) | NO OF BUS | $\|V\|$(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 0.98 | 18 | 0.99 | 24 | 0.95 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.02 | 20 | 0.94 | 26 | 0.96 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 1.05 | 10 | 1.02 | 16 | 0.97 | 22 | 0.94 | 28 | 1.01 |
| 5 | 1.05 | 11 | 0.98 | 17 | 1.01 | 23 | 1.02 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.02 | 19 | 0.95 | 25 | 0.98 |
| 3 | 1.05 | 9 | 1.05 | 15 | 1.02 | 21 | 0.94 | 27 | 0.95 |

Table 9: Power Flow Results With 120% of the Original Load and Transmission Lines

| NO OF BUS | \|***V***\|(P.U) | NO OF BUS | \|***V***\|(P.U) | NO OF BUS | \|***V***\|(P.U) | NO OF BUS | \|***V***\|(P.U) | NO OF BUS | \|***V***\|(P.U) |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.05 | 12 | 1.01 | 18 | 1.02 | 24 | 0.84 | 30 | 1.05 |
| 2 | 1.05 | 8 | 1.05 | 14 | 1.04 | 20 | 0.95 | 26 | 0.86 |
| 4 | 1.05 | 10 | 1.04 | 16 | 1.00 | 22 | 0.68 | 28 | 1.02 |
| 5 | 1.05 | 11 | 1.01 | 17 | 1.03 | 23 | 1.04 | 29 | 1.05 |
| 1 | 1.05 | 7 | 1.05 | 13 | 1.04 | 19 | 0.94 | 25 | 0.96 |
| 3 | 1.05 | 9 | 1.05 | 15 | 1.03 | 21 | 0.98 | 27 | 0.95 |

Table 10: Synchronous Power Coefficients with the Original load.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.4747 | 1.8080 | 6.4069 | 1.6020 | 1.2017 | 12.7060 | 1.0031 | 93.8050 | 6.4069 | 1.6020 |
| 3.4747 | 4.4000 | 3.2205 | 1.1085 | 1.1006 | 125.8000 | 1.1027 | 4.6078 | 3.2205 | 1.1085 |
| 1.8080 | 4.4000 | 1.7013 | 1.1059 | 6.2099 | 15.0560 | 15.0094 | 2.1078 | 1.1059 | 6.2099 |
| 6.4069 | 3.2205 | 1.7013 | 122.9000 | 41.4040 | 10.5029 | 1.0260 | 10.9097 | 41.4040 | 10.5029 |
| 1.6020 | 1.1085 | 1.1059 | 122.9000 | 4.3066 | 1.7093 | 1.0120 | 1.8032 | 1.1059 | 122.9000 |
| 1.2017 | 1.1006 | 6.2099 | 41.4040 | 4.3066 | 1.4055 | 6.5014 | 1.2081 | 4.3066 | 1.4055 |
| 12.7060 | 125.8000 | 15.0560 | 10.5029 | 1.7093 | 1.4055 | 1.5046 | 16.0750 | 1.7093 | 1.4055 |
| 1.0031 | 1.1027 | 15.0094 | 1.0260 | 1.0120 | 6.5014 | 0.546 | 1.0044 | 1.0120 | 6.5014 |
| 93.8050 | 4.6078 | 2.1078 | 10.9097 | 1.8032 | 1.2081 | 16.0750 | 1.0044 | 1.8032 | 1.2081 |
| 6.4069 | 3.2205 | 1.1059 | 41.4040 | 1.1059 | 4.3066 | 1.7093 | 1.0120 | 1.8032 | 4.3066 |
| 1.6020 | 1.1085 | 6.2099 | 10.5029 | 122.9000 | 1.4055 | 1.4055 | 6.5014 | 1.2081 | 4.3066 |

Table 11: Synchronous Power Coefficients with the Original load and SVC.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.4747 | 1.8080 | 6.4069 | 1.6020 | 1.2017 | 12.7060 | 1.0031 | 93.8050 | 6.4069 | 1.6020 |
| 3.4747 | 4.4000 | 3.2205 | 1.1085 | 1.1006 | 125.8000 | 1.1027 | 4.6078 | 3.2205 | 1.1085 |
| 1.8080 | 4.4000 | 1.7013 | 1.1059 | 6.2099 | 15.0560 | 15.0094 | 2.1078 | 1.1059 | 6.2099 |
| 6.4069 | 3.2205 | 1.7013 | 122.9000 | 41.4040 | 10.5029 | 1.0260 | 10.9097 | 41.4040 | 10.5029 |
| 1.6020 | 1.1085 | 1.1059 | 122.9000 | 4.3066 | 1.7093 | 1.0120 | 1.8032 | 1.1059 | 122.9000 |
| 1.2017 | 1.1006 | 6.2099 | 41.4040 | 4.3066 | 1.4055 | 6.5014 | 1.2081 | 4.3066 | 1.4055 |
| 12.7060 | 125.8000 | 15.0560 | 10.5029 | 1.7093 | 1.4055 | 1.5046 | 16.0750 | 1.7093 | 1.4055 |
| 1.0031 | 1.1027 | 15.0094 | 1.0260 | 1.0120 | 6.5014 | 0.546 | 1.0044 | 1.0120 | 6.5014 |
| 93.8050 | 4.6078 | 2.1078 | 10.9097 | 1.8032 | 1.2081 | 16.0750 | 1.0044 | 1.8032 | 1.2081 |
| 6.4069 | 3.2205 | 1.1059 | 41.4040 | 1.1059 | 4.3066 | 1.7093 | 1.0120 | 1.8032 | 4.3066 |
| 1.6020 | 1.1085 | 6.2099 | 10.5029 | 122.9000 | 1.4055 | 1.4055 | 6.5014 | 1.2081 | 4.3066 |

**Table 12:** Synchronous Power Coefficients with the Original load and Transmission lines

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.5747 | 1.9080 | 6.5069 | 1.7020 | 1.3017 | 12.8060 | 1.1031 | 93.9050 | 6.5069 | 1.7020 |
| 3.5747 | 4.5000 | 3.3205 | 1.2085 | 1.2006 | 125.9000 | 1.2027 | 4.7078 | 3.3205 | 1.2085 |
| 1.9080 | 4.5000 | 1.8013 | 1.2059 | 6.3099 | 15.1560 | 15.1094 | 2.2078 | 1.2059 | 6.3099 |
| 6.5069 | 3.3205 | 1.8013 | 122.9100 | 41.5040 | 10.6029 | 1.1260 | 10.9197 | 41.5040 | 10.6029 |
| 1.7020 | 1.2085 | 1.2059 | 122.9100 | 4.4066 | 1.8093 | 1.1120 | 1.9032 | 1.2059 | 122.9100 |
| 1.3017 | 1.2006 | 6.3099 | 41.5040 | 4.4066 | 1.5055 | 6.6014 | 1.3081 | 4.4066 | 1.5055 |
| 12.8060 | 135.8000 | 15.1560 | 10.6029 | 1.8093 | 1.5055 | 1.6046 | 16.1750 | 1.8093 | 1.5055 |
| 1.1031 | 1.1027 | 15.1094 | 1.1260 | 1.1120 | 6.6014 | 0.646 | 1.1044 | 1.1120 | 6.6014 |
| 93.9050 | 4.7078 | 2.2078 | 10.9197 | 1.9032 | 1.3081 | 16.1750 | 1.1044 | 1.9032 | 1.3081 |
| 6.5069 | 3.3205 | 1.2059 | 41.5040 | 1.2059 | 4.4066 | 1.8093 | 1.1120 | 1.9032 | 4.4066 |
| 1.7020 | 1.2085 | 6.3099 | 10.6029 | 122.9100 | 1.5055 | 1.5055 | 6.6014 | 1.3081 | 4.4066 |

## IV. CONCLUSION:

In this article, SSS improvement is achieved through the application of SPC. Power flow is performed, and the networks are modified by implementing voltage stability improvements through the incorporation of an SVC at weak buses, strengthening weak transmission lines, and topologically weak transmission lines. The SVC method has better voltage improvement than the enhancement of transmission lines. The power losses for the 30bus, 330 kV, Nigerian network are 219.08 MW, 185.46 MW, and 156.70 MW for the original, SVC and additional parallel transmission lines respectively. The same trend is observed for the 6-bus IEEE test network. SSS is performed on the original and modified networks after a gradual load addition of 20%. The results show improvement in SSS for the modified networks compared with the original network. The modified networks with additional transmission lines for the two case networks have a better improvement in SSS, while the SSS of using the SVC method has no significant effect on SSS compared with the original network. Since SSS has to do with inertia of the system during load addition, the inertia of the modified network with transmission lines is higher than the inertia of the SVC.

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