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A Comprehensive Review of FACTS Controllers in Nigeria Power Systems Network for Enhanced Performance on Variable Loads

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ABSTRACT: Interest on FACTS controllers in the scientific and engineering community have increased due to their high reliability, low cost, and absence of infrastructural overhauling. In the context of global sustainability, it is required that FACTS controllers must fulfill physical, technological, and environmental requirements, through design and optimization studies. This study provides a comprehensive evaluation of the state-of-the-art technologies relevant to multi-objective optimization and performance analysis of FACTS controllers. Types, general overview, FACTS deployed in the Nigerian power systems and multi-objective location optimization and their impact were discussed. Several efficient optimization strategies from recent research works are highlighted and compared, showing that there are research gaps on the integration of advanced control algorithms and use of robust optimization methods.

KEYWORDS: FACTS controllers, enhanced performance, variable loads, optimization strategy, location optimization

I. INTRODUCTION

The rising energy demand due to advancement in technology and population growth throughout the country in recent time as forecasted in (Nkan & Okpo, 2016), have resulted to expansion of power generation harnessed from several sources. Irregularity in power demands due to varying loads have significant impacts on the voltage profile, dynamic performance and stability of the grid frequency, particularly on inductive loads such as induction machines which have wide applications in commercial homes and industrial settings. These problems compromise the optimal performance of power system network. It becomes imperative to explore advance strategies to compensate the poor performance of power system equipment so as to enhance dynamic performance and system stability. Flexible alternating current transmission systems (FACTS) are power electronic devices to improve the power transfer capacity and controls in conventional AC transmission networks. Their application enhances power transfer capability, which improves the voltage stability, transient stability, voltage regulation, network reliability, and thermal limits. Prior to the advent of power electronics switches, challenges in power system were traditionally addressed by employing capacitor, reactor, and synchronous generator facilitated by mechanical switches. This posed serious issues such as slow response time and susceptibility to wear and tear in power system equipment. The conventional methods are unreliable for enhancing the controllability and stability of the transmission lines. Introduction of power electronic switches, such as Thyristors suitable for high-voltage applications, leads to the development of power electronic-based FACTS controllers. In power system network, effective coordination between the generation and electric power demand is imperative, due to the escalating demand for electrical energy. To meet this growing demand, optimizing the operation of all components at their maximum capacity becomes essential (Rao, Amarnath, and Rao, 2014; Abunike, Umoh, Nkan, & Okoro, 2021; Okpo, Okoro, Awah, & Akuru, 2020; Okoro, Abunike, Akuru, Awah, Okpo, Nkan, Udenze, Innocent, & Mbunwe, 2022; Okpo. Okoro, Akuru, & Awah, 2019). Extensive review on various categories of electrical power system including active, reactive and apparent power and their impacts on power system network was discussed in (Liu, Heydt, & Edris, 2002; Omorogiuwa & Okpo, 2015; Williams, Okpo, & Nkan, 2023; Edifon, Nkan, & Ben, 2016). To ensure stability in power system network, the capacitive and inductive reactive power must be in equilibrium. This is achieved through compensation techniques (Farahmand, Rashidinejad, Gharaveici, & Shojaee, 2006; Nelson & Odion, 2023; Innocent, Nkan, Okpo, & Okoro, 2021; Hu, Xiang, Zhang, Liu, Wang, & Hong, 2019). Studies in (Prajapati & Gandhi, 2018; Zhang, Hu, Xu, & Yan, 2015; Innocent, Nkan, Okpo, & Okoro, 2021; Ezeonye, Okpo, Nkan, & Okoro, 2020), categorizes various FACTS devices according to types of connections and their compensation techniques, grouping them into series and shunt compensators.

A. *Series Compensation*

Series compensator devices are used to improve the available transfer capability (ATC) in high voltage and extra high voltage transmission networks. The integration of series compensator decreases the phase angle between voltage and current and significantly improves the system stability. Shown in Fig. 1 is the diagram of series compensated transmission line.

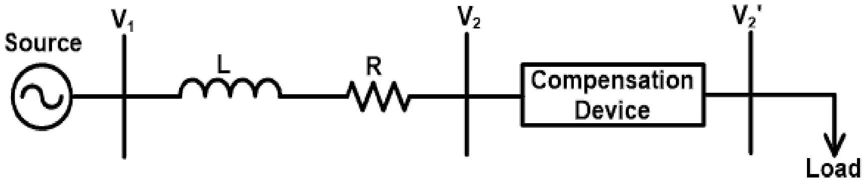


Fig 1. Series compensator (Farahmand *et al*, 2006)

B. *Shunt Compensation*

Shunt compensation techniques are deployed in overloaded transmission networks to boost or bulk the voltage as required. The reactive power demand is established by the line capacitance and high demand of reactive power will amount to significant drop in voltage. This necessitate the incorporation of capacitor banks at the receiving end of the transmission lines to boost the voltage. However, under light loads condition, the reactive power increases leading to imbalance in sending end and receiving end voltage. This can be controlled by introducing a shunt reactor. The shunt compensated power system network is represented in Fig. 2.

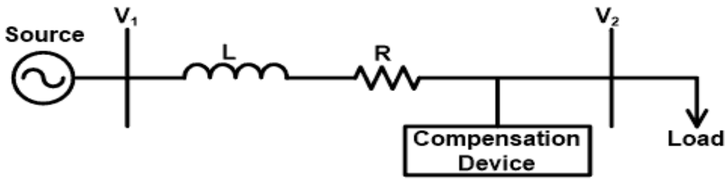


Fig. 2. Shunt compensator diagram (Zhang *et al*, 2015)

FACTS controllers are basically classified according to connections as depicted in Fig. 3.

i. Series connected controller
ii. Shunt connected controller
iii. Combined series-series controller
iv. Combined shunt-series controller

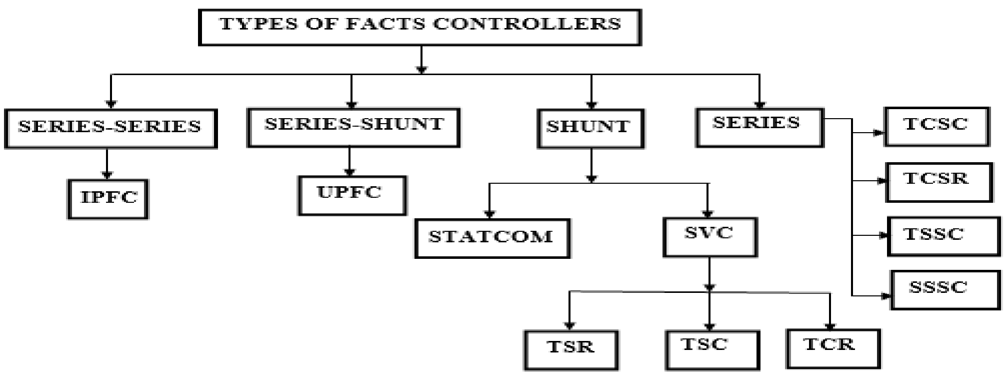


Fig. 3. Types of FACTS devices

i. Series connected controller

This consist of capacitors or reactors used to control variable reactive power in the transmission network. It induces voltage in series with the line voltage and the capacitor bank are usually introduced at the receiving end to compensate for voltage drop while reactors are introduced when there is less demand for reactive power (Sinha, Karan, & Singh; Awah, Okoro, Nkan, & Okpo, 2022; Ezeonye, Nkan, Okpo, & Okoro, 2022). The diagram of series compensated transmission network is represented in Fig. 4.

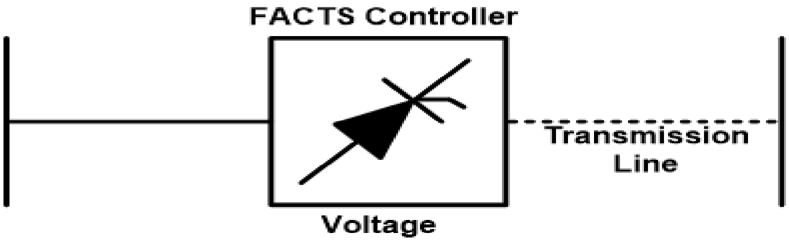
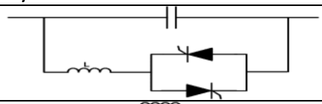
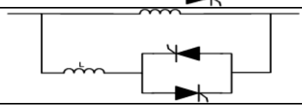
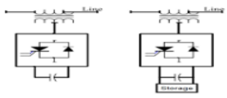


Fig. 4. Series Connected FACTS controller (Xiao *et al* 2000)

The various types of series connected controllers includes: Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Series Reactor (TCSR), Thyristor Switched Series Capacitor (TSSC) and Static Synchronous Series Compensator (SSSC). The diagrams of the basic types of series FACTS controllers are presented in Table 1.

Table 1. Types of Series FACTS Controllers

Series Connected FACTS Controllers	Symbols
Thyristor Controlled Series Capacitor (TCSC)	
Thyristor Controlled Series Reactor (TCSR)	
Static Synchronous Series Compensator (SSSC)	

ii. Shunt connected controller

This controller shares similar characteristics with the series connected controller. It consists of capacitors and inductors use for reactive power control in the power system network. When the transmission line is inductive, it operates on a lagging power factor to ensure system stability (Xiao, Song, & Sun; Oduleye, Nkan, & Okpo, 2023; Edifon, Nkan, & Macaulay, 2016). The diagram of static connected FACTS is shown in Fig. 5.

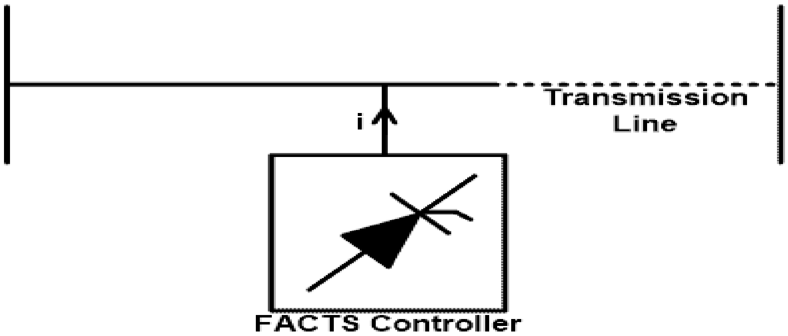
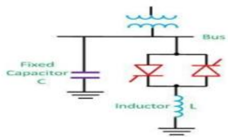
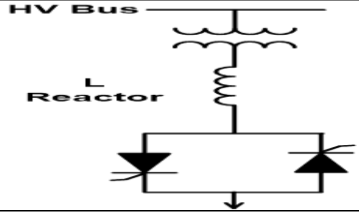
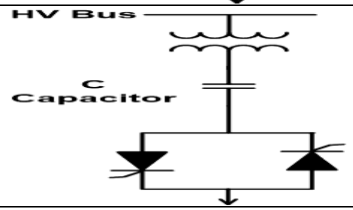
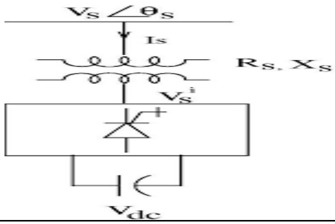


Fig. 5. Static connected FACTS

The various types of shunt FACTS controllers respectively deployed in the power system network includes: Static Var Compensator (SVC), Thyristor Control Reactor (TCR), Thyristor Switched Capacitor (TSC), Thyristor Switched Reactor (TSR), Static Synchronous Compensator (STATCOM). Shown in Table 2 is the various types of shunt connected FACTS controllers.

Table 2. Types of Shunt connected FACTS Controllers

Shunt connected FACTS Controllers	Symbols
Static Var Compensator	

Thyristor Controlled Reactor	
Thyristor Switched Capacitor	
Static Synchronous Compensator	

iii. Series-series controller

This controller finds application in multi lane transmission lines. A combination of series controllers in a coordinated manner provides independent series reactive compensation for each line. Reactive power also can be transferred through power link or connected through unified controller interlinked with the DC terminals of the converters. This enable real power transfer within the transmission network. Shown in Fig. 6 is the diagram of combined series-series FACTS controller (Yao, Cartwright, Schmitt, & Zhang, 2005; Okpo & Nkan, 2016).

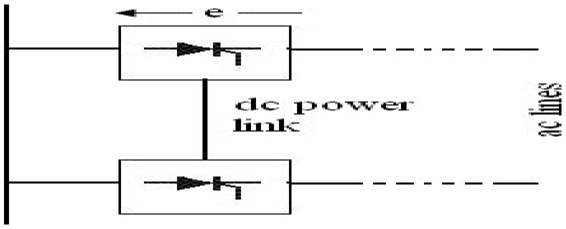


Fig. 6. Series-Series Compensator (Edifon *et al*, 2016)

A typical example of this FACTS controller is Interline Power Flow Controller (IPFC) represented in Fig. 7.

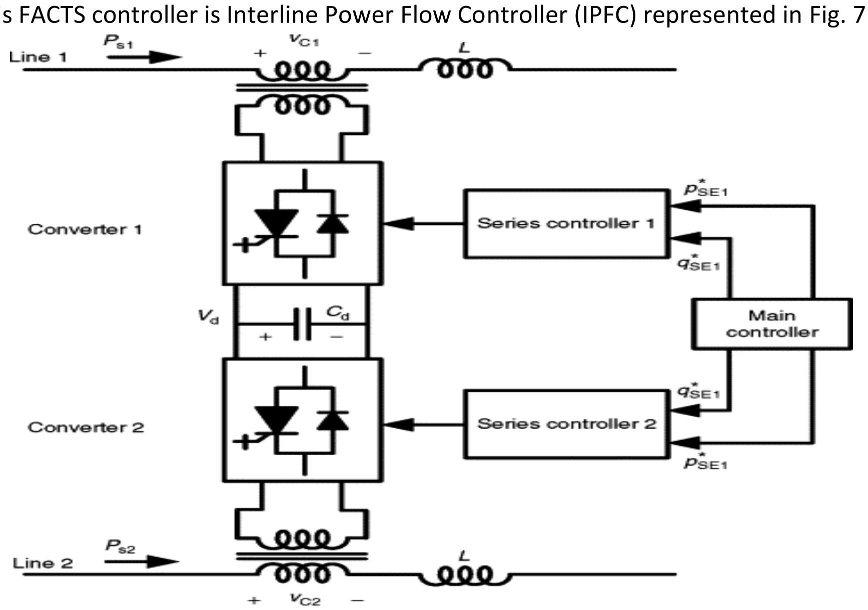


Fig. 7. Interline Power Flow Compensator (Okpo & Nkan, 2016)

iv. Shunt-series controller

This consist of shunt and series controllers operating in a coordinated manner. It is used for current and voltage control. Figure 8 represents a combined shunt-series FACTS controller.

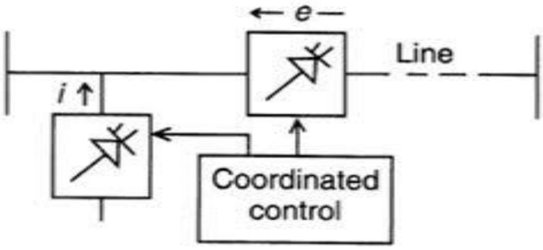


Fig. 8. Combined shunt-series FACTS (Edifon *et al*, 2016)

Example of this FACTS controller is the Unified Power Flow Controller. It controls the real and reactive power of the transmission line and function only on balance 3-phase systems. It is represented in Fig. 9.

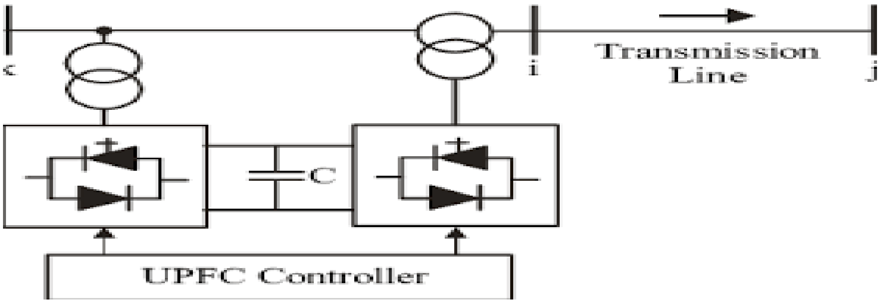


Fig. 9. UPFC FACTS (Zhang & Yokoyama, 2007)

II. OVERVIEW OF FACTS CONTROLLERS

The complexity of power system network requires a large scale control models so as to ensure optimal power flow within the power system network. Power system stabilizers integrated with excitation control system for synchronous generators, provides solution to this challenge by enhancing power system stability and reliability. Flexible alternating current transmission system (FACTS) significantly improve the dynamic performance and stability of the power system network. The investigation on performance of power system network when Fractional Order Fish Migration Optimization (FOFMO) algorithm utilizing fractional calculus (FC) theory, was deployed for dynamic regulation of the non-linear controller, showed significant improvement in control accuracy and the dynamic characteristics of a controlled power system (Fathollahi & Andresen, 2023). Due to increase in energy demand, modern power system is designed to accommodate distributed generators (DGs) and flexible alternating current transmission system (FACTS) controllers to improve the voltage profile and provides compensation effects for active and reactive power losses. The comprehensive review on various FACTS controllers deployed in power system network to improve the power quality and the Significant impacts on the grid studied in (Singh, Payasi, & Shukla, 2017; Kavitha, 2023; Singh, Verma, Mishra, Maheshwari, Srivastava, & Baranwal, 2012), deployed advanced techniques such as Hybrid techniques and multitask objectives for optimal placement of distributed generators (DGs) and FACTS controllers to enhance the performance of the power system network. Technology advancement have resulted to the innovation of environmental friendly transport system known as the electric vehicle (EVs). This necessitate studies on the impact EVs have on the power system network and optimal placement of electric vehicles (EVs) charging stations at strategic locations to enhance stability of the radial distribution system (RDS), due to their increase usage in order to enhance their safe operation. The revolutionary meta heuristics optimization provides solution to the challenges encountered during strategic placement of DSTATCOM and DGs using the Bald eagle search algorithm (BESA). The proposed system was validated using the two network bus system (34-bus system and 118- bus system), with the outcome showing a notable improvement in the overall system performance. This make BESA a good alternative for loss reduction in radial distribution system (Yuvarah, Devabalaji, Thanikanti, Aljafari, & Nwulu, 2023). Faults in power system network leads to severe contingencies necessitating proper evaluation of the fault magnitude so as to ensure the system reliability and safe operation within prescribed limit. The steady state contingency analysis of single (N-1) contingencies of IEEE 39-bus system using Newton Raphson method demonstrated in PSS/E software, presents a promising solution to most of these severe contingencies (Rehman, Farooq, Ahmad, Khan, Haq, Ayaz, & Saad, 2023; Nakiganda, Catherine, & Spyros, 2023). The present study is therefore significant as it will carry out an extensive review on various FACTS controllers deployed in power system networks and explore their significant impacts towards improving the power system parameters such as voltage profile, power quality, reduction of active power losses, dynamic performance and power system stability. Also this study will explore the FACTS devices already deployed in Nigerian power system network.

FACTS controller may be defined as an intelligent electronic device that is optimally positioned or placed within power system networks which dynamically adjust the system voltage profile, impedance and phase angle for enhancement of grid stability and power quality. There are various types of FACTS controllers used in power system networks. The study in (Singh, Verma, Mishra, Maheshwari, Srivastava, & Baranwal, 2012), classified them under two major headings namely Thyristor controlled based FACTS and voltage source inverter FACTS controllers. Examples of the former includes TSC, TCR, FC-TCR, SVC, TCSC, TC-PAR etc. While the later includes SSSC, STATCOM, UPFC, GUPFC, IPFC, GIPFC, HPFC etc. Congestion in Power system network and poor penetration of renewable sources remain a significant focal point to power system engineers. However, the combination of FACTS controllers with transmission network expansion planning (TNEP) can remedy solution to these problems. Advance strategy to control Irregularity in power flow is a factor to consider when FACTS controllers are deployed. The study in (Wu, Tanneau, & Hentenryck; Labed, Zellagui, Benidir, Sekhane, & Tebbakh, 2023) proposed mixed-integer linear programming (MILP) known as the extended formulation and particle swarm optimization method to address the problem of congestion in power system network and to mitigate active power losses and improvement of the voltage profile in a standard IEEE 33 bus radial distribution network. The first and second generation of FACTS controllers deployed in the power system network presents some drawbacks that includes: Increased cost, bulky size and reliability issues leading to poor dynamic performance of the electric grid and reduction in power quality. The first generation includes: static Var compensator (SVC), Thyristor controlled series compensator (TCSC), Thyristor controlled phase shifting transformer (TCPST), and the second generation FACTS controllers includes: SSSC, STATCOM, UPFC and IPFC. Modern FACTS controllers address these challenges. Distributed FACTS controllers such as the enhance power flow controller (EPFC) studied in (Dhaked & Lalwani, 2017; Rao & Rao, 2015; Madhuranthaka & Manohar, 2016) depict some high qualities which addresses the gaps observed in previous generations of FACTS controllers. The study conducted in a particular loaded transmission line in the Etiopian power system network, showed significant improvement in dynamic performance and stability of the power system when FACTS controllers such as SVC, TCSC, and UPFC were respectively deployed into network to reduce the real power losses, improve the voltage profile and transient stability. The real power losses reduced to 9.54%, 37.24%, and 37.47% respectively (Adama, 2021; Kumar, Kumer, Srirambabu, & Nagulmeera, 2014). Comparative assessment of the cost incurred when the conventional method utilizing multi-machine system and modern methods utilizing FACTS controllers specifically, static VAr Compensator (SVC), Thyristor Controlled Series Capacitor(TCSC), Thyristor Controlled Voltage Regulator(TCVR), and Thyristor Controlled Phase Shifting Transformer (TCPST) for active and reactive power control was discussed in (Alabduljabbar & Milanovic, 2010; Sahu, Jhapse, & Sahu, 2015; Raval & Dwivedi, 2013). The study outcome after calculating the net present value revealed that FACTS controllers do not only have less cost in power generation but also improve the power transfer in power system network. The fuzzy c-means clustering technique together with initially estimated cluster identification criterion was used for optimal location of the voltage control area (VCAs) and placement of the SVC controller in (Garrido, Tellez, & Ortiz, 2023). The proposed technique was tested on 14-node and 30-node scheme to determine its proficiency. In order to facilitate cost saving, the linear voltage stability index (LVSI) was utilized for the arrangement of the compensators. The study outcome showed great improvement in the voltage profile when SVC was optimally placed. The study in (Mirsaeidi, Devkota, Wang, Tzelepsis, Abbas, Alshahir, & He, 2023; Beikbabaei & Mehrizi-sani, 2023; Sanchez-Mora, Villa-Acevedo, & Lopez-Lezama, 2023; Abderrahmane, M'hamdi, Mahammedi, Moussa, & Elbar, 2023) compared the major attributes and drawbacks of the traditional techniques used in enhancing the power system quality: optimal reactive power dispatch (ORPD), and the MOTH flame and grasshopper optimization algorithm (GOA). The outcome showed that UPFC and GUPFC have a better performance due to their high sensitivity and voltage regulation. Comprehensive study guiding the selection of ideal FACTS controllers, based on specific need in the power system network using PSO, Genetic algorithm (GA), Brainstorming Optimization Algorithm (BSOA), Gravitational Search Algorithm (GSA), Moth Flame Algorithm (MFA), Imperialistic Competitive Algorithm (ICA), and Adaptive Cuckoo Search Algorithm (ACSA), was conducted in (Gaur & Mathew, 2023; Bhole & Nigam, 2015; Ghaffarzadeh, Marefatjou, & Soltain, 2012; Bharathi & Rajan, 2011). The study conducted in (Gupta & Mallik, 2022; Divya, Prakash, & Bhaskar, 2018; Cakir & Radman, 2013), used the contingency ranking together with the degree centrality methods, leveraging novel FACTS controllers into the power system network, residue factor method to optimally placed the FACTS controller in the power system. Voltage stability critically index method was used to optimally place STATCOM, SSSC and UPFC. The study in Shahgholian & Faiz, 2010; Bhande & Chandrakar, 2013; Hemallath; Fughar & Nwohu, 2014) explored extensively, STATCOM controllers, including plant, modelling, operation aspects, control fundamentals, and performance evaluation. The study also cover optimal method of placing STATCOM in the power system network. Three models of the STATCOM device were also presented. This facilitate a comprehensive understanding on functionalities of STATCOM FACTS controllers and effective method of placement. Energy crisis is a significant challenge faced by power system engineers resulting to the rising demand in energy consumption from the distribution sector. FACTS controllers including SVC, SSSC, UPFC, and IPFC ameliorate these issues. The unified power flow controllers (UPFC) emerges as a more viable solution due to its versatility in real and reactive power control and voltage regulation, offering an effective means to mitigate the energy crisis and improved overall system performance. The proposed system was validated in MATLAB-Simulink (Khan, Narasimhegowda, Mohan, & Manjunatha, 2014). A comprehensive review carried out in (Dixon, Moran, Rodriguez, & Domke, 2005), delves into the reactive power control, operational principles, design characteristics and practical applications of VAR compensators implemented using Thyristors, and self-commutated converters. Studies in (Ameh & Onyedikachi, 2018; Mohammed & Abdul-Rahim, 2004; Nguyen, Le, Phan, & Nguyen, 2023; Olana, 2021), carried out an intensive research on the root cause of voltage instability and voltage drop emanating from the active and reactive power demand within the power system transmission network using Coot bird behavior-based optimization algorithm (COOTBA) and PSAT in MATLAB environment. The study in (Tolba, Houssein, Ali, & Hashim, 2023; Fawzy, Abd-Raboh, & Eladi, 2023; Agrawal, Bharadwaj, & Kothari, 2016; Rehman, Koondhar, Ali, Jamali, & El-Sehiemy, 2023), deployed novel methods to improve the system performance. This is the modified capuchin search algorithm (mCapSA), bilevel multi-objective musical chairs optimization algorithm, and meta-heuristic method to mitigate transmission losses and enhance overall efficiency. In order to mitigate severe contingencies in power system network, the study in (Iranmanesh & Rashid-Nejab, 2013), deployed real genetic algorithm (RGA) optimization with evaluation of RGA fitness function which was conducted and verified in the IEEE 5 bus test system.

III. FACTS CONTROLLERS DEPLOYED IN NIGERIAN POWER SYSTEMS

FACTS deployed in Nigerian power system network plays a crucial role in enhancing grid stability and control. They provide real-time adjustment to voltage and reactive power, helping to mitigate voltage instability and power oscillations. The ant colony optimization algorithm technique presents tactical approach towards optimal placement of STATCOM device in the Nigerian 330 kV network. It has the capacity to decode the STATCOM parameters using some mathematical models for optimal location and placement of the STATCOM device (Fughar & Nwohu, 2014). Three FACTS controllers namely TCSC, UPFC and IPFC were respectively deployed in NEPLAN, using the continuation power flow (Natala, Nkan, Okoro, & Obi, 2023), improve proposed applicable technique. The outcome showed that UPFC outperformed TCSC and IPFC. The MATLAB code extracted was used to determine the available transfer capability with and without FACTS. Novel methods to alleviate stress in the power system network due to overloading condition caused by the rising population and advancement in technology was carried out in (Oleka, Ndubisi, & Ijemaru, 2016; Nkan, Okpo, & Okoro, 2020; Ayodele, Ogunjuyigbe, & Oladele, 2016) using voltage stability sensitivity factor (VSSF) in PSAT environment and the step-by-step approach to enhance performance of the Nigerian 330kV electric power grid. The application of FACTS devices for the enhancement of transient and steady state stability in the Nigerian 48-bus power system network was discussed in (Nkan, Okoro, Obi, Awah, & Akuru, 2019; Nkan, Okoro, Awah, & Akuru, 2019; Adebisi, Adejumobi, Ogunbowale, & Ade-Ikuesan, 2018) using continuation power flow. SVC, STATCOM, and SSSC were respectively deployed to determine the response of the system when three phase fault was introduced. Voltage stability is a prerequisite for enhancement of power quality. Studies in (Folorunso, Osuji, & Ighodalo, 2014; Ugwuanyi, Uma, & Ekwue, 2021) investigated this problem using modal sensitive analysis to identify the fault-sensitive locations and respective generators involved. The study conducted in (Nkan, Okpo, & Inyang, 2023; Ambafi, Nwohu, Ohize, & Tola, 2012; Bakare, Aliyu, Haruna, & Abu, 2012; Sanni, 2014), focused on the Nigerian 48-bus power system utilizing PSAT software in MATLAB to examine the response of the generator parameters when a three phase fault was applied on Bus 33 and the TCSC optimally placed on line 21-28 using continuation power flow, small population-based particle swarm optimization (SPPSO) for optimal tuning of Unified Power Flow Controllers (UPFC), and python programming using the application programming interface (API) to enhance the voltage profile, power flow along lines, and the damping of the power system oscillations. The investigation on the dynamic control capabilities of UPFC in enhancing system security, by optimizing its placement using the differential evolution (DE) technique was conducted in (Mustapha, Musa, Bakare, Bukar, Modu, Gwoma, Benisheikh, & Buji, 2017). This was applied to the IEEE14 bus power system using MATPOWER. The outcome showed robustness of the UPFC in minimizing real power losses and improving the voltage profiles under various steady state conditions. The conventional methods of addressing power system issues like reactive power imbalance and voltage instability on heavily loaded transmission lines presents significant challenges. Alternative approach to address such issues is by deploying FACTS devices to provide compensation to power oscillations. The investigation carried out in Nigerian 330kV transmission system using MATLAB, showed enhancement in the voltage magnitudes (Adeniji & Mbamaluikem, 2017; Oluwagbade, Wura, Adejumobi, & Mustapha, 2015; Nkan, Okpo, & Okpura, 2023; Essien, Odion, &

Chukwu, 2023; Omoigui, Lawal, & Alao, 2017). Extensive review carried out in (Adepoju & Tijani, 2014; Amaize, Anthony, Claudius, & Abel, 2017; Ajabuego & Olubiwe, 2019), explored the accompanied benefits in deploying various FACTS controllers into the Nigerian 330kV transmission network. Emphasis are on the present challenges faced in the Nigerian power system network such as voltage instability, erratic power supply and security of supply which could be addressed by integration of various FACTS controllers into the power system network. The study in (Nkan, Okoro, Awah, & Akuru, 2019; Nkan, Okpo, Akuru, & Okoro, 2020) also carried out an investigation using static synchronous series compensator (SSSC) and Thyristor Controlled Series Compensator (TCSC), to enhance steady-state stability in the Nigerian 48-Bus power system network using the voltage stability sensitivity factor (VSSF) in all the buses after performing continuation power flow (CPF). A comparative study carried out in [97,98,99] assessed the performance of FACTS devices namely STATCOM and SSSC to address the challenge of voltage instability and power loss in the Nigerian 330 kV electric power grid using Newton Raphson power iterative algorithm. Effective mitigation measures to issues of voltage collapse phenomenon was explored in [100,101], using the fault tree method and heuristic approach to identify the weak buses in the Nigerian-26 bus system. The study in [102,103,104], deployed IPFC, STATCOM, HVDCVSC, and UPFC into the Nigerian 330 kV system to improve the voltage profile at the weak buses using GA, flexible alternating current transmission system power flow (FACTSPF), and small population-based particle swarm optimization (SPPSO) to adjust the bus voltage, transmission line reactance and the phase angle between two buses. The simulation conducted on the Nigerian grid system in the PSAT environment showed appreciable improvement in voltage profile, power flow, and damping of power oscillations with the installation.

IV. MULTI-OBJECTIVE LOCATION OPTIMIZATION OF FACTS AND THEIR IMPACTS

The various methods use for optimal placement of FACTS in the reviewed literature and their significant impacts in the power system parameters is presented in the Table 3 and the summary in Table 4. The pie chart of Fig. 10 depicts the percentage application of the various optimization techniques employed in the placement of FACTS controllers in Nigeria.

Table 3. Comparison of different optimization methods of FACTS controllers

Ref	Optimization Method	Voltage Profile	Power Quality	Dynamic Stability	Voltage Stability	Power Transfer capability	Transient stability	Validation Method
[67]	CPF	No	No	No	No	Yes	No	Simulation
[10]	Dynamic Response	No	No	Yes	No	No	No	Simulation
[72]	VSSF and CPF	No	No	Yes	No	No	No	Simulation
[21]	Least square method	No	Yes	No	No	No	No	Analysis
[54]	Meta-Heuristic	Yes	No	No	No	Yes	No	Simulation
[70]	Step-by–step technique	No	No	Yes	No	No	Yes	Simulation
[73]	Newton Raphson	Yes	NO	No	No	Yes	No	Simulation
[77]	GA	No	No	Yes	No	No	No	Simulation
[75]	Modal analysis	No	NO	Yes	No	No	No	Simulation
[98]	SPPSO	Yes	No	Yes	No	Yes	No	Simulation
[80]	Differential Evolution	No	No	No	No	Yes	No	Simulation
[94]	SPEA	No	No	Yes	No	No	No	Simulation
[26]	BESA	Yes	No	Yes	No	Yes	No	Simulation
[24]	Fuzzy based approach	No	No	Yes	Yes	No	No	Simulation

[28]	GNN	No	Yes	No	No	Yes	No	Simulation
[59]	COOTBA	No	No	No	Yes	Yes	No	Simulation
[43]	MFO and GOA	No	No	Yes	Yes	Yes	No	Simulation
[22]	FOFMO	No	No	Yes	Yes	No	Yes	Simulation
[45]	VSI	No	No	Yes	Yes	Yes	Yes	Simulation
[61]	mCapSA	Yes	No	No	No	Yes	No	Simulation
[62]	MCOA	No	Yes	No	Yes	No	No	Simulation
[65]	RGA	Yes	No	No	Yes	No	yes	Simulation
[50]	Residue Factor	No	No	Yes	Yes	Yes	No	Simulation
[62]	Musical chairs algorithm	No	Yes		Yes	Yes	No	Simulation

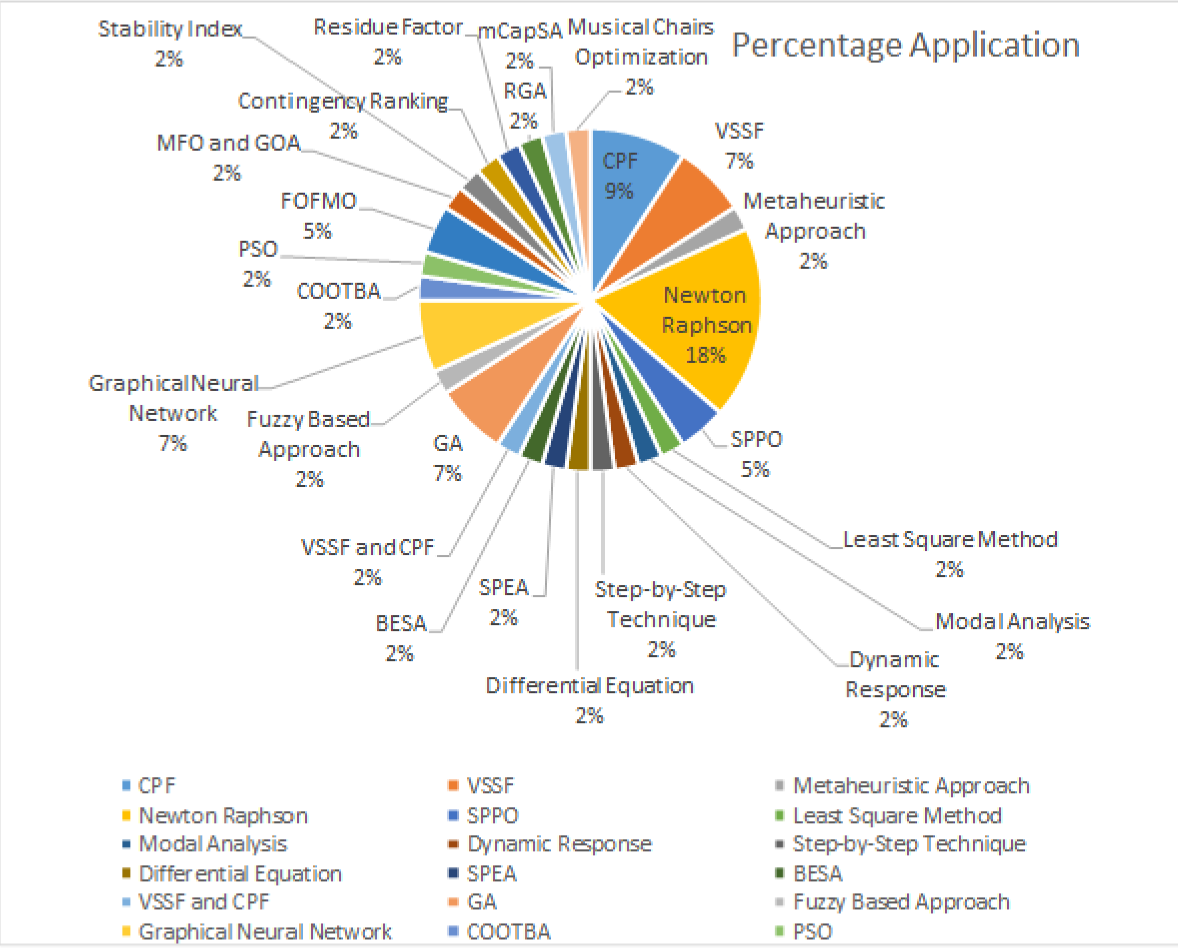


Fig. 10: Different optimization method used for placement of FACTS devices

Table 4. Summary of optimization methods and percentage application

Optimization Method	**Percentage Application**
Continuation power flow (CPF)	9
Dynamic Response	2
Voltage stability sensitivity factor and CPF	2
Least square method	2
Meta-Heuristic	2
Step-by–step technique	2

Newton Raphson	18
Genetic Algorithm (GA)	7
Modal analysis	2
Small population particle swarm optimization (SPPSO)	5
Differential Evolution	2
Strength pareto evolutionary algorithm (SPEA)	2
Bald eagle search algorithm (BESA)	2
Fuzzy based approach	2
Graph neural network (GNN)	7
Coot bird behavior-based optimization algorithm (COOTBA)	2
MOTH flame optimization (MFO) and the grasshopper optimization algorithm (GOA)	2
Fractional Order Fish Migration Optimization (FOFMO)	5
Voltage stability index (VSI)	2
Modified capuchin search algorithm (mCapSA)	2
Musical chairs optimization (MCO)	2
Real genetic algorithm (RGA)	2
Residue Factor	2

V. CONCLUSIONS

This work is a detailed overview of FACTS optimization methods employed in Nigerian power system in particular, including existing performance analysis strategies for reducing real and reactive power loses and improving the system steady state and dynamic stability. The results of several multi-objective optimization methods, including genetic algorithms, particle swarm optimization method etc, applied to the installation of FACTS, are explored and contrasted.

REFERENCES

1) Abderrahmane, A., M'hamdi, B., Mahammedi, A., Moussa, M. A., & Elbar, M. (2023). FACTS Devices Optimal Placement and Parameter Setting to Improve Power Network System Performance . Semiconductor Optoelectronics , 42(2), 368-386.
2) Aborisade, D. O., Adebayo, I. G., & Oyesina, K. A. (2014). A Comparison of the Voltage Enhancement and Loss Reduction Capabilities of STATCOCM and SSSC FACTS Controllers . American Journal of Engineering Research (AJER), 3(1), 96-105.
3) Abunike, C. E., Umoh, G. D., Okpo, E. E., & Okoro, O. I. (2020). A Comparative Approach for the Analysis of Switched Reluctance Motors with Modified Rotor Pole Geometry. Nigerian Journal of Engineering, 27(3), 2705-3954.
4) Abunike, E. C., Umoh, G. D., Nkan, I. E., & Okoro, O. I. (2021). Investigating the Magnetic Characteristics of 12/8 Switched Reluctance Motor for Enhanced Starting Torque. Nigerian Journal of Technological Development, 18(1).
5) Adama, O. (2021). Investigation of the Dynamic Stability and Performance of Koka-Dire Dawa [Eastern Region] HVAC Line with SVC, TCSC and UPFC. Haramaya: Haramaya University.
6) Adebisi, O. I., Adejumobi, I. A., Ogunbowale, P. E., & Ade-Ikuesan, O. O. (2018). Performance Improvement of Power System Networks Using Flexible Alternating Transmission Systems Devices: The Nigerian 330kV Electricity Grid As a Case Study . LAUTECH Journal of Engineering and Technology, 12(2), 46-55.
7) Adeniji, O. A., & Mbamaluikem, P. O. (2017). Voltage Stability Enhancement and Efficiency Improvement of Nigerian Transmission System Using Unifield Power Flow Controller. American Journal of Engineering Research, 6(1), 37-43.
8) Adepoju, G. A., & Tijani, M. A. (2014). A Survey of FACTS Controller Applications to Nigerian Transmission System. International Academy of Science, Engineering and Technology, 3(2).
9) Adepoju, G. A., Komolafe, O. A., & Aborisade, D. O. (2011). Power Flow Analysis of the Nigerian Transmission System Incorporating FACTS Controllers . International Journal of Applied Science and Technology, 1(5).
10) Agrawal, R., Bharadwaj, S. K., & Kothari, D. P. (2016). Simulation Tool for FACTS Controllers-"A Review". International Journal of Development Research, 6(4), 7409-7416.
11) Ajabuego, O. G., & Olubiwe, M. (2019). Comparative Analysis of Different FACTS Devices on Expanded Port Harcourt Network. Intrnational Journal of Engineering Research and Technology (IJERT), 8(8), 290-295.

12) Alabduljabbar, A. A., & Milanovic, J. V. (2010). Assessment of Techno-Economic Contribution of FACTS Devices to Power System Operation . Electric Power Systems Research, 80, 1247-1255.

13) Amaize, P., Anthony, A., Claudius, A., & Abel, A. (2017). A Review of the Applications of FACTS Devices on Nigerian 330kV Transmission System. Journal of Engineering and Applied Sciences , 12(20), 5182-5185.

14) Ambafi, J. G., Nwohu, M. N., Ohize, H. O., & Tola, O. J. (2012). Performance Evaluation of PSS and STATCOM on Oscillation Damping of a North-Central Power Network of Nigeria Grid System. International Journal of Engineering and Technology , 2(2), 209-219.

15) Ameh, B. V., & Onyedikachi, N. S. (2018). Review, Comparison and Similarities of Static Var Compensator (SVC) and Thyristor Control Series Series Capacitor (TCSC) With Other (FACTS0 Devices . Iconic Research and Engineering Journals, 2(3).

16) Awah, C. C., Okoro, O. I., Nkan, I. E. & Okpo, E. E. (2022). Impact of structural dimensions and poles on the torque performance of dual-stator permanent magnet machines. Nigerian Journal of Technological Development, 19(1), 68-79.

17) Ayodele, T. R., Ogunjuyigbe, A. S., & Oladele, O. O. (2016). Improving the Transient Stability of Nigerian 330kV Transmission Network using Static Var Compensation Part 1: The Base Study. Nigerian Journal of Technology (NIJOTECH), 35(1), 155-166.

18) Bakare, G. A., Aliyu, U. O., Haruna, Y. S., & Abu, U. A. (2012). Transient Enhancement of Ngerian Grid System Using Optimally Tuned Based on Small Population Particle Swarm Optimization. Asian Journal of Natural and Applied Sciences , 1(3), 79-89.

19) Bakare, G. A., Aliyu, U. O., Haruna, Y. S., & ABU, U. A. (2012). Transient Enhancement of Nigerian Grid System Using Optimally Tuned UPFC Based on Small Population Particle Swarm Optimization. 1(3).

20) Beikbabaei, M., & Mehrizi-Sani, A. (2023). Series FACTS Devices for Increasing Resiliency in Severe Weather Conditions. energies, 16(16).

21) Bhande, S. A., & Chandrakar, V. K. (2023). Enhancement of Power System Security by the Intelligent Control of a Static Synchronous Series Compensator . Engineering, Technology and Applied Science Research , 13(5), 11953-11958.

22) Bharathi, R., & Rajan, C. C. (2011). An Advanced Fact Controller for Power Flow Management in Transmission System Using IPFC. International Conference on Process Automation Contol and Computing , (pp. 1-6). Coimbatore, India.

23) Bhole, S. S., & Nigam, P. (2015). Improvement of Voltage Stability in Power System by Using SVC and STATCOM. International Journal of Advanced Research in Electrical Electronics and Instrumentation Engineering , 4(2).

24) Cakir, G., & Radman, G. (2013). Placement and Performance Analysis of FACTS -CONTROLLERS (SVC and STATCOM for Damping Oscillation. 3rd International Conference on Electric Power and Energy Conversion Systems , (pp. 1-5). Istanbul, Turkey.

25) Dhaked, D. K., & Lalwani, M. (2017). A Comprehensive Review on a D-FACTS Controller: Enhanced Power Flow Controller (EPFC). International Journal of Advanced in Engineering and Technology, 10(1), 84-92.

26) Divya, R., Prakash, S., & Bhaskar, C. (2018). Minimizing Power Losses and Power Quality Improvement Using FACTS Controllers Using DPFC. International Journal of Pure and Applied Mathematics , 118(18), 291-299.

27) Dixon, J., Moran, L., Rodriguez, J., & Domke, R. (2005). Reactive Power Compensation Technology, State-of-the-Art Review. Proceedings of the IEEE , 93(12), 2144-2164.

28) Edifon, A. I., Nkan, I. E., & Ben, I. A. (2016). Estimation and ranking of the photovoltaic energy potential for local government areas in Akwa Ibom State, Nigeria. Science Journal of Energy Engineering, 4(6), 68-77.

29) Edifon, A. I., Nkan, I. E., & Macaulay, E. U. (2016). Comparative analysis of the performance of different photovoltaic (PV) technologies based on PVsyst thermal model. Science Journal of Energy Engineering, 4(6), 62-67.

30) Essien, U. J., Odion, J., & Chukwu, N. F. (2023). Performaance Evaluation of Optimally Placed SVC for Dynamic Stability of the Power System. International Journal of Multi-Disciplinary Research and Analysis, 6(11), 5120-5129.

31) Ezeonye, C. S., Okpo, E. E., Nkan, I. E., & Okoro, O. I. (2020). Effects of Saliency and Core Losses on the Dynamic Behaviour of Permanent Magnet Synchronous Motor. Bayero Journal of Engineering and Technology (BJET), 15(3), 124-133.

32) Farahmand, H., Rashidinejad, M., Gharaveici, A. A., & Shojaee, M. (2006). An Application of Hybrid Heuristic Approach for ATC Enhancement. Large Engineering Systems Conference odn Power Engineering. Halifax, NS, Canada.

33) Fathollahi, A., & Andresen, B. (2023). Multi-Machine Power System Transient Stability Enhancement Utilizing a Fractional Order-Based Nonlinear Stabilizer . MDPI, 7(11), 808.

34) Fawzy, S., Abd-Raboh, E., & Eladi, A. (2023). Optimal Allocation of Multi-Type FACTS Devices for Mitigating Wind Power Spillage with Enhancing Voltage Stability and Social Welfare. Scientific Report, 13.

35) Folorunso, O., Osuji, C. C., & Ighodalo, O. S. (2014). Enhancement of Power System Voltage Stability with the Aid of Reactive/Capacitive Power Swithching Mechanism (A Case Study of Owerri Transmission Company of Nigeria). Journal of Advancement in Engineering and Technology, 2(1), 2348-2931.
36) Fughar, A., & Nwohu, M. N. (2014). Optimal Location of STATCOM in Nigerian 330kv Network using Ant Colony Optimization Meta-Heuristic. Double Blind Peer Reviewed International Research Journal , 14(3), 2249-4596.
37) Garrido, C., Tellez, A. A., & Ortiz, L. (2023). Linear Voltage Stability Indicator (LVSI) for Optimal Placement of SVC Devices to Improve the Voltage Stability Margin in Transmission Systems . Electronics, 1(12), 2-26.
38) Gaur, D., & Mathew, L. (2023). Optimal Placement of FACTS devices Using Optimization Technique: A Review. 3rd International Conference on Communication Systems. San Francisco.
39) Ghaffarzadeh, N., Marefatjou, H., & Soltani, I. (2012). Investigation and Comparison of the Effects of FACTS Devices, Capacitors and Line Reactance Variation on Voltage Stability Improvement and Loadability Enhancement in Two Area Power System. International Journal of Applied Power Engineering (IJAPE), 1(3), 145-158.
40) Gupta, S. K., & Mallik, S. K. (2022). Enhancement in Voltage Stability Using FACTS Devices Under Contingency Conditions. Journal of Operation and Automation in Power Engineering .
41) Hemalatha, r. (n.d.). Flexible Alternating Current Transmission System . vijayamangalam.
42) Hu, S., Xiang, Y., Zhang, X., Liu, J., Wang, R., & Hong, B. (2019). Reactive Power Operability of Distributed Energy Resources for Voltage Stability of Distribution Networks. Power System Clean Energy, 7(4), 851-861. Retrieved from http://doi.org/10.1007/s40565-018-0484-3
43) Innocent, U. O., Nkan, I. E., Okpo, E. E., & Okoro, O. I. (2021). Dynamic Response Evaluation of a Separately Excited DC Motor . Nigeria Journal of Engineering, 28(2).
44) Innocent, U. O., Nkan, I. E., Okpo, E. E., & Okoro, O. I. (2021). Predicting the Stability Behaviour of Three-Horse Power Induction Motor Using Eigenvalue Method. Bayero Journal of Engineering and Techcnology (BJET), 16(2), 66-81.
45) Iranmanesh, H., & Rashid-Nejab, M. (2013). Using UPFC and IPFC Devices Located by a Hybrid Meta-Heuristic Approach to Congestion Relief. Energy and Power Engineering , 5, 474-480.
46) Kavitha, K. (2023). Fuzzy based optimal placement of tcsc-svc to enhance system security. International Journal of Management, Technology and Engineering, 9(5).
47) Khan, A., Narasimhegowda, T. R., Mohan, K. R., & Manjunatha, B. (2014). Power Quality Enhancement By Using UPFC. International Journal of Engineering Research and Technology (IJERT), 3(6).
48) Kumar, K. C., Kumer, S. M., SriramBAbu, V., & Nagulmeera, S. (2014). A Comparative Analysis of UPFC as a Power Flow Controller with Application. IOSR Journal of Electrical and Electronics Engineerirng (IOSR-JEEE) , 9(4), 28-36.
49) Labed, M. A., Zellagui, M., Benidir, M., Sekhane, H., & Tebbakh, N. (2023). Optimal Hybrid Photovoltaic Distributed Generation and Distributed Static Synchronous Compensators Planning to Minimize Active Power losses Using Adaptive Acceleration Coefficients Particle Swarm Optimization Algoritms. Electrical Engineering and Electromachanics (6), 1-15.
50) Liu, C. C., Heydt, G. T., & Edris, A. A. (2002). Impacts of FACTS controllers odn transfer capability of power grids," in Proceedings of the Power Engineering Society Transmission and Distribution Conference. Proceedings of the Power Engineering Society Transmission and Distribution Conference. , New York, NY, United States.
51) Madhuranthaka, T., & Manohar, G. T. (2016). A Review on Power System Voltage Stability and Optimization Techniques . International Journal of Engineering Research and Aplication, 6(11), 6-14.
52) Mirsaeidi, S., Devkota, S., Wang, X., Tzelepis, D., Abbas, G., Alshahir, A., & He, J. (2023). A Review on Optimization Objectives for Power System Operation Improvement Using FACTS Devices . energies, 16(1).
53) Mohammed, A. A.-M., & Abdel-Rahim. (2004). Optimal power flow with FACTS devices, Roorkee, India.
54) Mustapha, M., Musa, B., Bakare, G., Bukar, A., Modu, B., Gwoma, Z., . . . Buji, A. (2017). Dynamic Analysis of Power Loss Minimization and Voltage Profile Enhancement Using UPFC Devices with Differential Evolution Algorithm. European Journal of Advances in Engineering and Technology, 4(1), 36-43.
55) Nakiganda, A. M., Catherine, C., & Spyros, C. (2023). Topology-Aware Neural Networks for Fast Contingency Analysis of Power Systems. arXiv .
56) Natala, H., Nkan, I. E., Okoro, O. I., & Obi, P. I. (2023). Investigation of the Transfer Capability of the Nigerian 330kV, 58-Bus Power System Network Using FACTS Devices . Journal of Electrical Engineering, 22(1), 53-62.
57) Nelson, F. C. & Odion, J. (2023). Core loss reduction in induction motor using finite element analysis. Journal of Multidisplinary Engineering Science and Research (JMESR) , 2(9), 242-247, 2023.

58) Nguyen, A. T., Le, C. K., Phan, M. T., & Nguyen, T. T. (2023). Coot Bird Behavior-Based Optimization Algorithm For Optimal Placement Of Thyristor Controlled Series Compensator Devices In Transmission Power Networks. Power engineering and electrical engineering, 21(3).
59) Nkan, I. E., & Okpo, E. E. (2016). Electric power forecasting by the year 2020 using the least square method. International Journal of Research and Advancement in Engineering Science, 6(1).
60) Nkan, I. E., Okoro, O. I., Awah, C. C., & Akuru, U. B. (2019). Investigating the Dynamic Stability of the Nigerian 48-Bus Systems for Improved System Performance using FACTS. Proceedings of the 27th Domestic use of Energy Conference.
61) Nkan, I. E., Okoro, O. I., Awah, C. C., & Akuru, U. B. (2019). Investigating the Steady State Stability of the Nigerian 48-Bus Systems using FACTS Devices. Nigerian Journal of Technology (NIJOTECH), 38(3), 732-743.
62) Nkan, I. E., Okoro, O. I., Obi, P. I., Awah, C. C., & Akuru, U. B. (2019). Application of FACTS Devices in a Multi-Machine Power System for Transient Stability Enhancement: A Case Study of the Nigerian 330kV 48-Bus System . IEEE AFRICON, (pp. 1-9). Accra, Ghana.
63) Nkan, I. E., Okpo, E. E., & Inyang, A. B. (2023). Enhancement of Power System Transient Stability with TCSC: A Case Study of The Nigerian 330kV, 48-Bus Network. International Journal of Multidisciplinary Research and Analysis, 6(10), 4828-4841.
64) Nkan, I. E., Okpo, E. E., & Okoro, O. I. (2020). Multi-Type FACTS Controllers for Power System Compensation: A Case Study of the Nigerian 48-Bus, 330kV System. Nigerian Journal of Technological Development, 63-69.
65) Nkan, I. E., Okpo, E. E., & Okpura, N. I. (2023). Optimum Location of Shunt FACTS Devices for Enhancement of Power System Loadability Using Continuation Power Flow. International Multilingual Journal of Science and Technology (IMJST), 8(9).
66) Nkan, I. E., Okpo, E. E., Akuru, U. B., & Okoro, O. I. (2020). Contingency Analysis for Improved Power System Stability of the Nigerian 330Kv, 48-Bus System using Series FACTS Controllers. AIUE Congress 2020: International Conference on Use of Energy.
67) Oduleye, A. E., Nkan, I. E. & Okpo, E. E. (2023). High impedance fault detection and location in the Nigerian 330 kV transmission network using adaptive neuro-fuzzy inference system. International Journal of Multidisciplinary Research and Analysis, 6(11), 5390-5398.
68) Okoro, O. I., Abunike, C. E., Akuru, U. B., Awah, C. C., Okpo, E. E., Nkan, I. E., Udenze, P. I., Innocent, U. O., & Mbunwe, M. J. (2022). A Review on the State-of-the-Art Optimization Strategies and Future Trends of Wound-Field Flux Switching Motors. IEEE PES/IAS PowerAfrica, (pp. 1-5). Kigali, Rwanda.
69) Okpo, E. E., & Nkan, I. E. (2016). Construtional Features and Performance Analysis of 3-Phase Linear Induction Motor. International Journal of Scientific Innovations and Sustainable Development , 6(1).
70) Okpo, E. E., Nkan, I. E., Okoro, O. I., & Akuru, U. B. (2021). Winding Reconfiguration of 5.5 kW Three-Phase Induction Motor for Improved Performance. IEEE PES/IAS PowerAfrica, (pp. 1-4). Nairobi, Kenya.
71) Okpo, E. E., Ogbonnaya, I. O., Chukwuemeka, C. A., & Udochukwu, B. A. (2020). Investigating the Dynamic Behaviour of a Six Phase Induction Motor under Unbalanced Faults. IEEE PES/IAS Power Africa, (pp. 1-5). Nairobi, Kenya.
72) Okpo, E. E., Ogbonnaya, O. I., Udochukwu, B. A., & Chukwuemeka, C. A. (2019). Performance Evaluation of 5.5kW Six-Phase Asynchronous Motor. IEEE PES/IAS Power Africa, (pp. 639-644). Abuja, Nigeria.
73) Olabisi, O. P. (2010). Optimal Power Flow Solution to Voltage Collapse in a Deregulated Electricity Market. Lagos.
74) Olana, A. (2021). Investigation of The Dynamic Stability and Performance of Koka—Dire Dawa [Eastern region] HVAC Line With SVC, TCSC, And UPFC. Haramaya.
75) Oleka, E. U., Ndubisi, S. N., & Ijemaru, G. K. (2016). Electric Power Transmission Enhancement: A Case of Nigerian Electric Power Grid . American Journal of Electrical and Electronic Engineering , 4(1), 33-39.
76) Oluwagbade, Z. V., Wara, S. T., Adejumobi, I. A., & Mustapha, A. O. (2015). Effects of Unifield Power Flow Controller on Power System Performance: A Case Study of Maryland 132/33/11 kV Transmission Station. International Journal of Engineering Technologies and Advanced Engineering, 5(6).
77) Omoigui, M., Lawal, O. A., & Alao, R. A. (2017). Improving dthe Nigerian 330kV Power System Steady State Voltage Stability Using Static Var Compenstaion and Genetic Algorithm Optimization . CARD International Journal of Engineering and Emerging Scientific Discovery, 2(2).
78) Omorogiuwa, E., & Okpo, E. E. (2015). PV-Diesel Hybrid Power System for a Small Village in Nigeria. International Journal of Scientific Research Engineering Technology , 1(4).

79) Omorogiuwa, E., & Onohaebi, S. (2015). Optimal Location of IPFC in Nigeria 330kV Integrated Power Network Using GA Technique. Electrical and Electronic Systems , 4(1).

80) Prajapati, S. M., & Gandhi, P. R. (2018). Impacts of FACTS Devices for ATC Enhancement in Deregulated Market. International Conference on Power Energy, Environment and Intelligent Control (PEEIC). Greater Noida, India .

81) Rao, N. S., Amarnath, J., & Rao, V. P. (2014). Comparison fo Performance of Multitype FACTS devices on available transfer capability in a deregulated power system. International Conference on Smart Electric Grid (ISEG), (pp. 1-6). Guntur, India.

82) Rao, S. R., & Rao, S. V. (2015). A generalized approach for determination of optimal location and performance analysis of FACTS devices . Electrical Power and Energy Systems, 73, 711-724.

83) Raval, M., & Dwivedi, V. V. (2013). Commencing the FACTS in Variable Energy Sources Network to Optimize Existing Transmission System with Stability. International Journal of Emerging Trends in Electrical and Electronics (IJETEE), 2(1).

84) Rehman, A. U., Farooq, A., Ahmad, I., Khan, S., Haq, I., Ayaz, A., & Saad, M. (2023). Steady State Contingency Analysis of IEEE-39 Bus System Using PSS/E. International Journal of Advanced Natural Science and Engineering Researches, 7(7), 78-85.

85) Rehman, A., Koondhar, M. A., Ali, Z., Jamali, M., & El-Sehiemy, R. A. (2023). Critical Issues of Optimal Reactive Power Compensation Based on an HVAC Transmission System for an Offshore Wind Farm. Sustainability, 15(19).

86) Sahu, A. K., Jhapse, R., & Sahu, A. K. (2015). Avaialble Transfer Capability Enhancement By Using UPFC. International Journal of Applied Science Engineering and Management , 1(2), 15-22.

87) Sanchez-Mora, M. M., Villa-Acevedo, W. M., & Lopez-Lezama, J. M. (2023). Multi-Area and Multi-Period Optimal Reactive Power Dispatch in Electric Power System. energies, 16(17).

88) Sanni, S. O. (2014). Assessment of Transient Stability Enhancement Capability of Unifield Power Flow Controller in a Multi-Machine Power System. Zaria: Ahmadu Bello University.

89) Shahgholian, G., & Faiz, J. (2010). Static Synchronous Compensator for Improving Performance of Power System: a Review. International Review of Electrical Engineering (I.R.E.E), 5(5).

90) Singh, B., Payasi, R. P., & Shukla, V. (2017). A taxanomical review on impact assessment of optimal placed DGs and FACTS controllers in power systems. ScienceDirect, 3, 94-108.

91) Singh, B., Verma, k. S., Mishra, P., Maheshwari, R., Srivastava, U., & Baranwal, A. (2012). Introduction to FACTS Controllers: A Technological Literature Survey . International Journal of Automation and power Engineering , 1(9).

92) Sinha, N., Karan, S., & Singh, S. K. (2015). Modifield DE Based ATC Enhancement Using FACTS Devices . International Conference on Computational Intelligence and Networks. Odisha, India.

93) Tochukwu, O. O. (2012). Improved Energy Efficiency Using FACTS-Device Technique: A Cases Study of Ogui-Enugu Power Distribution Network. Ogui-Enugu: Afribary.

94) Tolba, M. A., Houssein, E. H., Ali, M. H., & Hashim, F. A. (2023). A New Robust Modified Capuchin Search Algoritm for the Optimum Amalgamation of DSTATCOM in Power Distribution Network. Neural Computing and Applications.

95) Ugwuanyi, N. S., Uma, U. U., & Ekwue, A. O. (2021). Fundamental Study of Oscillations in the Nigerian Power System. Nigerian Journal of Technology (NIJOTECH), 40(5), 913-926.

96) Williams, E. A., Okpo, E. E., & Nkan, I. E. (2023). Performance evaluation of induction motor behaviour on conventional and PV system power sources. International Journal of Multidisciplinary Research and Analysis, 6(12), 5500-5511.

97) Wu, K., Tanneau, M., & Hentenryck, P. V. (2007). Strong-Mixed-Integer Formulations for Transmission Expansion Planning with FACTS Devices . IEEE transaction on Power Systems, 22(3), 1171-1180.

98) Xiao, Y., Song, Y. H., & Sun, Y. Z. (2000). Application of Stochastic Programming for Available Transfer Capability Enhancement using FACTS Devices. Power Engineering Society Summer Meeting(Cat.No.00CH37134. Seatle, WA, USA.

99) Yao, L., Cartwright, P., Schmitt, L., & Zhang, X. P. (2005). Congestion Management of Transmission System Using FACTS. IEEE/PES Transmission and Distribution Conference and Exposition . Asia and Pacific, Dalian.

100) Yuvaraj, T., Devabalaji, K. R., Thanikanti, S. B., Aljafari, B., & Nwulu, N. (2023). Minimizing the electric vehicle charging stations impact in the distribution networks by simultaneous allocation of DG and DSTATCOM with considering uncertainty in load. Energy Reports, 10, 1796-1817.

101) Zhang, J., & Yokoyama, A. (2007). Aplication of interline Power Flow Controller to ATC Enhancement by Optimal Power Flow Control . IEEE Lausanne Power Tech , (pp. 1226-1231). Lausanne, Switzerland.

102) Zhang, P., Hu, W., Xu, W., & Yan, F. (2015). Co-ordinated control of multi-FACTS based on Improved teaching and Learning algorithm to improve ATC. IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC0, Brisbane, QLD. Australia.