Review

A Review of Power Compensation Techniques: Challenges and Recommendations for Future Investigation

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Abstract: Power quality problem is a hot area in power systems and drives that has drawn the attention of many researchers. This is because of the threat it poses on the health of electrical systems and the cost incurred on utility bills. The problem arises as a result of the need for reactive power to be supplied alongside active power in power transmission and distribution. Unfortunately, reactive power is consumed by almost all components of the system, leading to a shortage. To solve this problem, there is a need to compensate for the lost reactive power. Several researchers have proposed various approaches to mitigate this problem such as thyristor switched capacitor bank, series compensator, series reactor, series var compensator (SVC), Static Synchronous Compensator (STATCOM), synchronous condenser and others. In order to further draw attention in this area, this work investigates a number of research papers on power compensation techniques and draw up challenges from each work that can be considered for further investigation. To this end, each research paper reviewed is evaluated in terms of problem solved, technique used, and results obtained. It therefore offers ample opportunities for researchers to explore in improving power quality and power system safety.

Keywords: electrical systems; power compensation techniques; multistage capacitor banks; power quality; power system safety; mines electrical power supply

1. Introduction

Alternating current (AC) is used for all phases of electrical power production, transmission, distribution, and consumption. But there are a few problems with using AC power. Reactive power requirements, which must be met in conjunction with active power, are one such example. Both leading and lagging reactive power are possible. Nearly every part of the system, from generators to cables to loads, contributes to or uses reactive power. Reactance is a component of reactive power in a circuit and can be inductive or capacitive. As a result, lagging reactive power must be supplied to the vast majority of inductive loads; this is known as compensation. Electric power compensation is the intentional insertion of capacitive or inductive reactive power devices into a power network to achieve particular effects such as higher voltage profiles, increased power factor, system stability, and transmission capacity[1]. The reactive devices are either parallel (shunt) or series coupled. Series capacitors are used to cancel out a portion of a power network's inductive reactance. Shunt capacitors supply capacitive reactive power to the system at the point of connection, primarily to compensate for the out-of-phase current component required by an inductive load

Today, there is increasing need for power compensation. For example, the Mines were only charged for the actual power they used (kWh), excluding the reactive component (kVAr) or the power factor. The Mine operators didn't give power factor adjustment any consideration because there were no repercussions for having a low power factor. Most mines were running at power factors as low as 0.4 p.u. Mining companies in Zambia are mandated by the utility to improve their power factor, or else pay substantial fines and pay higher energy prices. The Mines must now ensure that the power factor stays around the permitted range of 0.92 p.u. to 0.99 p.u. Sadly, majority of their loads are inductive devices, which necessitate much reactive power from the grid. To save money and stay out of trouble with energy suppliers, the customer must make up for reactive power. The network needs to be compensated to minimize the high cost and improve the efficiency of the system. Similarly, system and transmission line stability might be compromised due to reactive power consumption caused by transmission line impedance and the demand for lagging reactive power by most equipment in the generating system. Unnecessary voltage drops cause larger losses, which must be provided by the source. This increases stress on the system and increases the likelihood of line faults. Therefore, it is safe to say that these effects are nullified by reactive power compensation, which also aids in providing a more effective transitory response to faults and disturbances.

In view all these effects, there is greater attention being paid to the strategies used for compensation these days, and the inclusion of improved technology means that the compensation is more effective than ever before. This paper reviews various power compensation techniques, noting challenges and providing suggestions for future investigation. The remaining sections of the paper are organized thus. Section 2 reviews existing power compensation techniques. Section 3 evaluates research works under each technique and discusses notable challenges for future research. While section 4 concludes the paper.

2. Power Compensation Techniques

There are essentially two types of compensation strategies: Series and shunt compensation. In shunt compensation, Flexible Alternating Current Transmission System (FACTS) are connected in parallel with the power system transmission line. It functions as a source of controlled current. By adjusting the shunt impedance, a reactive current is introduced into the line to keep the voltage magnitude constant. As a result, the transmittable active power is raised at the expense of raising the demand for reactive power. Examples of shunt power compensation techniques are: Static Synchronous Compensator (STATCOM) and synchronous condenser. However, in series compensation, reactive power is added in series with the transmission line to increase the system's impedance to increase the line's capacity for electricity transfer. In series compensation, reactive power is added in series with the transmission line to increase the system's impedance. Example of series compensation techniques include: series compensator, series reactor, and series var compensator (SVC).

In this section a number of power compensation techniques built upon the shunt, series configuration or a combination of both are discussed. Devices such as thyristor switched capacitor bank, series compensator, series reactor, series var compensator (SVC), Static Synchronous

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Compensator (STATCOM) and synchronous condenser are discussed in detail.

2.1. Thyristor Switched Capacitor Bank

A thyristor-switched capacitor (TSC) is a type of equipment used in electrical power systems to compensate for reactive power. It has a thyristor switch as well as a capacitor bank [2]. There are at least two series-connected capacitor groups in the capacitor bank. A series circuit with a thyristor switch and an inductor coil is connected in parallel with a capacitor group that is isolated from another capacitor group via a mains power supply connection (see Figure 1). A thyristor-switched capacitor bank is thus obtained, with a thyristor switch that only needs to be built for a fraction of the mains power supply voltage itself, which is a significant economic advantage.

A TSC is a three-phase assembly that is typically connected in a delta or star configuration. In contrast to a TCR, a TSC produces no harmonics and thus does not require filtering. As a result, some SVCs have been built entirely of TSCs. This can lead to a low-cost solution in which the SVC only requires capacitive reactive power and the reactive power output can only be varied in steps. Only SVCs with a TCR or another variable element, such as a STATCOM can produce continuously variable reactive power output.

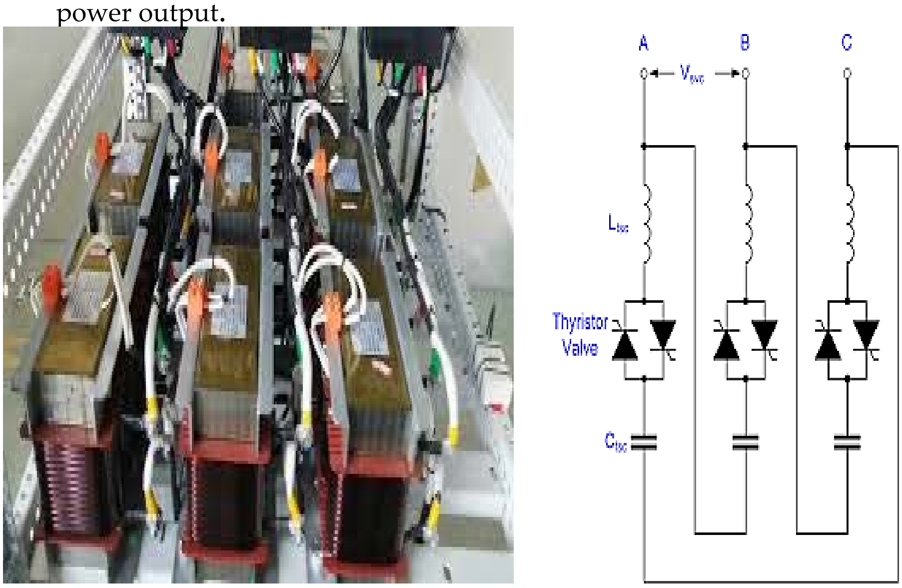

Figure 1. Thyristor switched capacitor bank [3].

2.2. Series Compensator

A series compensator is a type of flexible alternating current transmission system that consists of a solid-state voltage source inverter linked in series with a transmission line and a transformer. This device, when connected in series with the line, can inject a nearly sinusoidal voltage. To increase system voltage, they are connected in series to the transmission line. Series compensator technology is a well-established technique for reducing transfer reactance, particularly in bulk transmission corridors[4]. Figure 2 shows a circuit diagram of series compensator.

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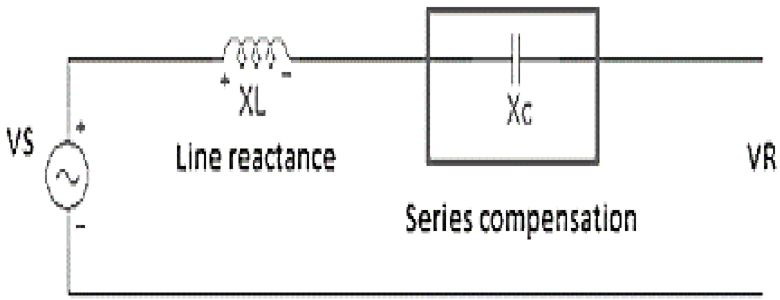

Figure 2. Series compensator.

2.3. Thyristor Switched Capacitor Bank

Series reactors are connected in series to power capacitors (see Figure 3). They suppress harmonics in the power grid and prevent problems caused by unusual events such as transient overcurrent and overvoltage that are generated by opening and closing of power capacitors [5]. Generally, the series reactor blocks the high-frequency signals or alternating current. In a parallel power network, they are typically used to limit the system's fault current or to facilitate proper load sharing. When a series reactor is connected to an alternator, it is referred to as a Generator Line Reactor. This is done to reduce stress in the event of a three-phase short circuit fault.

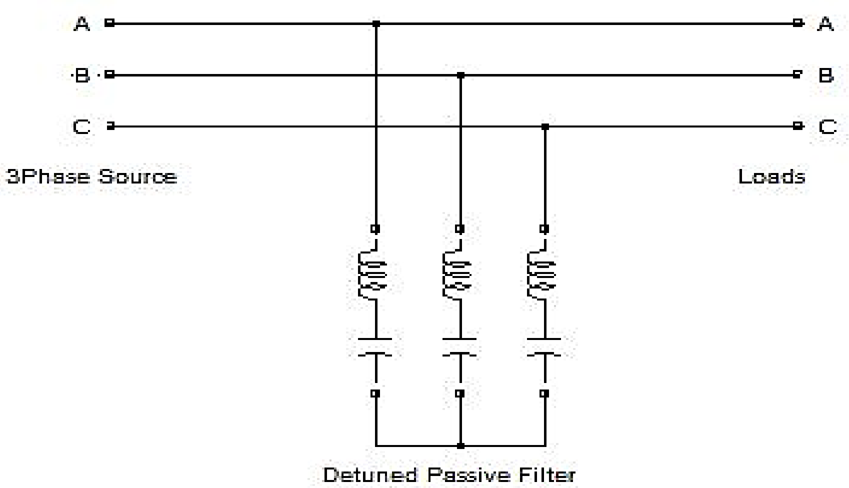

Figure 3. Series reactor [6].

2.4. Static VAR Compensator

A static VAR compensator (SVC) is a form of electrical devices that provide reactive power in high-voltage power transmission networks [7]. SVCs are devices that regulate voltage, power factor, harmonics, and system stability in the Flexible AC transmission system device family. The SVC is an impedance matching device that is used to bring the power factor of the system closer to unity. SVCs are used in two ways. They are connected to the power grid to regulate the transmission voltage ("Transmission SVC"). They are also linked in close proximity to large industrial loads to improve power quality ("Industrial SVC"). In transmission applications, the SVC is used to regulate grid voltage. If the power system's reactive load is capacitive (leading), the SVC will consume VARs from the system, lowering the system voltage. Under inductive (lagging) conditions, the capacitor banks are automatically turned on, resulting in a higher system voltage. Connecting a continuously variable thyristor-controlled reactor to a capacitor bank step results in continuously variable leading or lagging power. SVCs are typically used to smooth flicker voltage in industrial applications near high and rapidly varying loads, such as arc furnaces. The circuit diagram of a static var compensator is shown in Figure 4.

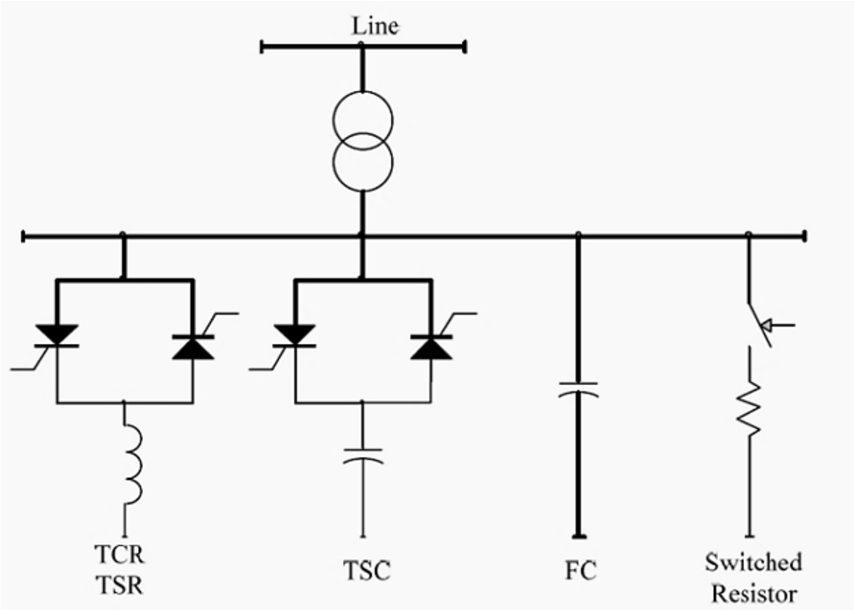

Figure 4. Static VAR compensator**.**

Where TCR, TSR and FC are thyristor controlled reactor, thyristor switched reactor and fixed capacitor respectively.

2.5. Static Synchronous Compensator

A static synchronous compensator (STATCOM) is an alternating current electricity transmission network shunt-connected regulating device (see Figure 5). It is based on a power electronics voltage-source converter and can act as a source or sink of reactive alternating current to a power grid [8]. It can also provide active alternating current power when connected to a power source. Voltage fluctuations can also be reduced using these compensators. A STATCOM is a VSC-based device that has the voltage source hidden behind a reactor. A STATCOM has very little active power capability because the voltage source is a DC capacitor. However, the active power capability of the DC capacitor can be increased by connecting a suitable energy storage device across it. The reactive power at the STATCOM terminals is proportional to the voltage source's amplitude. For example, if the VSC terminal voltage is greater than the alternating current voltage at the point of connection, the STATCOM generates reactive current (appearing as a capacitor); conversely, if the amplitude of the voltage source is less than the alternating current voltage, it absorbs reactive power (appears as an inductor).

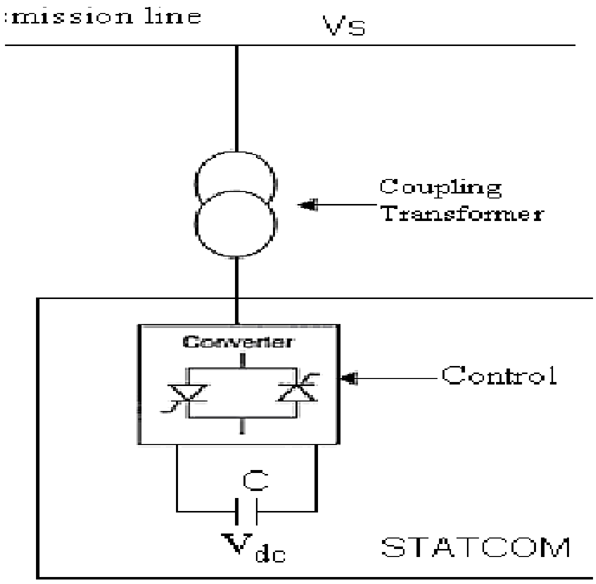

Figure 5. Static synchronous compensator [9].

2.6. Synchronous Condenser

Synchronous condensers can generate reactive power, and this power can be controlled [10]. Because of this regulating advantage, synchronous condensers are ideal for correcting the system's power factor. However, when compared to static capacitors, this equipment is quite expensive. As a result, synchronous condensers can only be employed to regulate the voltage of a very high voltage transmission system. Synchronous condensers are also known as dynamic power factor correction systems. These machines can be extremely effective when advanced controls are used. A PLC-based controller combined with a power factor controller and a regulator allows the system to be configured to meet a specific power factor or produce a specific amount of reactive power. In electric power systems, synchronous condensers can be used to control the voltage on long transmission lines, particularly lines with a relatively high ratio of inductive reactance to resistance. Figure 6 depicts a synchronous condenser model with AVR as the automatic voltage regulator.

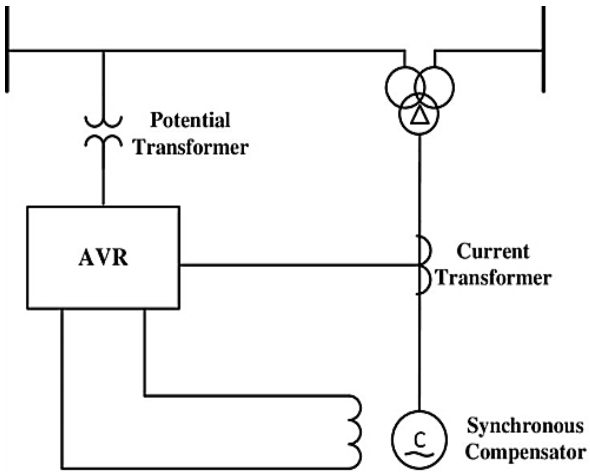

Figure 5. Synchronous condenser [11].

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3. Challenges and Recommendations for Future Investigation

This section presents a summary of a number of research papers on power compensation using the conventional techniques discussed in the precious section and other techniques. A systematic literature review approach was used to evaluate each research paper in terms of problem solved, technique used, and results obtained. Similarly, challenges are drawn from each work as recommendations for further investigation. Table 1 presents a summary of each work evaluated.

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Table 1. Review of power compensation techniques

SN	Problem solved	Type of compensation technique	Results	Challenges/ Recommendation	Ref.
1	Improving power quality in a smart grid system.	Static Var Compensator (SVC) based on the Thyristor Controlled Reactor (TCR)	Improved power quality in smart electrical grids using the proposed system.	SVC is a cost-effective technique for reactive power compensation and improvement of power factor. However, this work could be extended to obtain an easy process and better performance	[12]
2	Comparison of the effectiveness of the use of FACTS devices in bulk electrical networks to improve the efficiency of reactive power flow control and voltage regulation.	Shunt reactors and STATCOM technique were compared.	The use of FACTS devices improves the efficiency of active and reactive power flow control and voltage regulation in the network.	STATCOM is not cost effective compared to shunt reactors, also, the inductance value does not fall under the control range. However, STATCOM increases natural power.	[13]
3	Reactive power compensation method for 25KV 50HZ AC catenary system.	Synchronous capacitors.	Can be implemented to compensate for power factor, and static or dynamic reactive power.	It is difficult to use synchronous capacitors in a contact network of 25 kV, 50 Hz for the compensation of reactive power	[14]
4	Comparative review of reactive power compensation technologies.	Synchronous condensers, SVC, and STATCOM devices were reviewed and compared.	STATCOM has better dynamic behaviour and it can control more variables when compared to SVC and synchronous condenser.	The need for the development of better switching performance technologies to replace the Insulated-gate bipolar transistor (IGBT) and Integrated gate-commutated thyristor (IGCT) currently used in switching of power electronics devices. Also, the need for a hybrid-type large-capacity multilevel STATCOM devices to overcome several limitations currently faced by the current technology	[15]

5	Reducing fault currents and line losses in transmission system.	STATCOM and UPFC, and SSSC FACTS power compensation techniques.	Faults current is reduced significantly using UPFC and STATCOM though UPFC outperforms STATCOM.SSSC only acts as a voltage source.	The use of FACTS devices provides reliability while reducing costs.	[16]
6	Reactive power compensation and suppression of load imbalance in electrical power grid.	Three-phase star connected buck-type dynamic capacitor (D-CAP).	D-CAP can completely compensate for reactive powers and negative-sequence currents if the load is slightly unbalance	Due to limit of compensation ability, if the load is heavily unbalanced, it can only compensate for positive-sequence reactive power and part of the negative reactive-sequence.	[17]
7	A qualitative measure for reactive power compensation for reliability improvement.	Based on constructing a probability distribution function for the required reactive power compensation. A non-linear, AC power flow-based model is used to accurately represent system load curtailment remedial actions.	A quantitative measure for the amount of reactive power needed for the compensation in electrical subsystems was provided.	The proposed system was applied on a 24-bus test system. Real life simulations are needed to prove the workability of the system.	[18]
8	Comparative studies of the most common reactive power compensation techniques and a solution that aggregates these techniques for reactive power compensation was presented.	Techniques compared are, synchronous condensers, SVC, STATCOM, and inverters within wind-PV farms.	Integration of different compensation technologies will improve the flexibility of power plants and transmission system operator (TSO) in providing reactive power.	The system is designed for conventional power plants. Future work is to extend the strategy to accommodate other ancillary services.	[19]
9	Improving reactive power quality in an AC railway rural electrification system.	Static VAR compensator and the adaption of each train's reactive power.	Increase in railway energy efficiency system and reduction in reactive power consumption.	The deployment of a mobile reactive power compensation approach built on a smart metering framework can improve the quality of supply in the railway network.	[20]

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10	Improve power quality and power factor in electrical systems.	SVC and STATCOM techniques based on FACTS technology.	STATCOM technique outperforms SVC in areas such as voltage stability and harmonics mitigation whereas SVC is more cost effective.	Before selecting any compensating device, whether the SVC or STATCOM, a cost-benefit analysis should be performed.	[21]
11	Power factor improvement for linear loads.	Magnetic energy recovery switch (MERS).	Application of MERS reduced the reactive power demanded to almost zero thereby improving power quality.	There is need to validate the effectiveness of the proposed system on hardware systems.	[22]
12	Improving power quality in an electrical system.	Various FACTS such as SVC, STATCOM, and synchronous condenser techniques were compared.	Synchronous condenser was strongly suggested as a more efficient tool for enhancing the performance of power systems because it could be applied on a much larger scale	There is need to validate the results obtained on a grid setup	[23]
13	Improving power quality in electrical grids system.	The principle of independent individual phase compensation using capacitor batteries.	The proposed system is able to efficiently compensate for reactive powers.	There is need to protect capacitors from the influence of higher harmonics when compensating for reactive power.	[24]
14	Improving power quality in power transmission lines.	Static synchronous series compensator based on FACT technology.	Absorbs active power from transmission lines, compensates for reactive power thereby improving power quality	Experimental validation was based on simulation, there is need for a real-life case scenario to ascertain its efficiency.	[25]
15	The efficiency of STATCOM to compensate for reactive power in electrical grid.	STATCOM compensation technique based on FACTS system.	The use of STATCOM maintains the stability of the system and reduces the burden on the grid system while keeping the reactive power at zero.	Validation of the system was only implemented on a simulation platform.	[26]
16	Effectiveness of FACTS system in compensating for reactive power.	SVC, STATCOM and UPFC FACTS devices were compared.	FACTS devices outperform traditional capacitors techniques. Also, SVC proves to have overall better response under normal operation.	FACTS devices are expensive though they greatly improve voltage stability	[27]

17	Reducing power loss of distribution power networks using reactive power compensation.	Local compensation at each load to increase power factor and then capacitors in the distribution line. Particle swarm optimization (PSO), parasitism predation algorithm (PPA), and tunicate swarm algorithm (TSA) are applied on the proposed system.	The proposed compensation method is useful for distribution systems in minimizing total power loss.	The combination of local compensation at each load and compensation in distribution lines is very useful in reducing power loss of distribution systems.	[28]
18	Reactive power compensation that allows for education of active power flow.	The use of a reactive power compensation algorithm and a three-phase, four-wire AC/DC power converter with a separate neutral wire and undeterred by unbalanced grid situations is the basis for the proposed solution.	The proposed technique can reduce active power on the output of the reactive power compensator from 103.5 W to 2.1 W and yet function effectively with a weak microgrid	In the case of microgrids, the use of the three-level, four-wire converter with independent control of each phase has a great potential for compensating for reactive current, but the correct algorithm for appropriate synchronization must be used.	[29]
19	Increase power quality and reduce line loss in power systems.	Based on a fixed capacitor FC and STATCOM FACTS devices.	Proposed system reduces compensation cost, and active power loss.	Validity of the proposed system is based on simulations real life case study is recommended.	[30]
20	Compared various reactive power compensation techniques available.	STATCOM, TCR, SVC, TCSC were studied and compared	STATCOM is a feasible option for voltage control in small-scale power allocation systems.	VSM based STATCOM is proposed for future works.	[31]
21	Analysis of various power compensation technique.	It is noted that, D-STATCOM is able to quickly and accurately compensate reactive power, thus enhancing the power quality of the system	It is noted that, D-STATCOM is able to quickly and accurately compensate reactive power, thus enhancing the power quality of the system	There have been numerous studies on the detecting link, but there are still certain limitations in the actual engineering, so widespread implementation is still ways off.	[32]

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22	Reducing power quality problem	Hysteresis band current controller (HBCC)-based static synchronous compensator (STATCOM)	The total harmonic distortion of the system's voltage and current was reduced by 0.25% and 0.35%, respectively. Also, a reactive power demand of 30 kVAR was met	HBCC-based STATCOM is a more robust technique for improving power quality and reactive power compensation. Also, analysis tool available in the MATLAB/Simulink system are still within IEEE Standard 519–1992 limitations.	[33]
23	Reduction of Power loss and total cost of energy finding the most appropriate size and site of capacitor banks for distribution system.	Modified stochastic fractal search (MSFS) algorithm.	Reduced the power losses of the systems by 0.002%, 0.003%, and 0.18%, respectively.	Proposed method can effectively be applied in determining the site and size of capacitors in distributed networks.	[34]
24	Reactive power compensation in a single-phase system	Single-phase reactive power compensation control for static compensator (STATCOM)	Simulation results using MATLAB/SIMULINK showed that the power factor increased from about 0.7 to almost ideal value of 1	Results obtained from simulations validate the effectiveness of the proposed system, however real life implementation is recommended.	[35]
25	Improvement of voltage profile and reduction of power loss under constant and varying load conditions	Optimal capacitor allocation technique using the modified Honey Bee Mating Optimization Algorithm (HBMO)	Numerical results showed that the proposed algorithm is effective	The authors concluded that the HBMO technique can provide a globally optimum solution	[36]
26	Reactive power compensation in wind farm	A multi-objective optimization technique based on an improved genetic algorithm	Reactive power of wind motors was optimized in terms of voltage quality, active power loss, and node voltage deviation	The problem of complex current collection networks in wind turbines was not considered in this work.	[37]
27	Reduction in switching losses and proper management in the flow of current and voltage	Parallel IGBT-Based Interline Dynamic Voltage Restorer (PIGBT- IDVR)	The results of the proposed module provided better compensation than the existing system	Multilevel inverter concept can be employed in future works to power electronic system with medium operating voltage.	[38]
28	Active power compensation in a single-phase power grid	A self-tuning filter-frequency locked loop (STF-FLL) based control algorithm	The performance of the proposed system satisfied the objectives of the proposed	The control scheme proposed can be effectively utilized when the power generation from renewable sources is zero.	[39]

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			scheme and the IEEE-519 standard.		
29	Reduction of real power losses in a radial distribution system.	Salp swarm algorithm (SSA) and whale optimization algorithm (WOA). Installation of multi-DG units simultaneously in three phases unbalanced IEE-13 and IEE-123 node.	The proposed method is able to locate the best position and size for the DG units compared with WOA and SSA. Results showed that the total real power losses on the tested systems were decreased by 34.4% and 26.5%	It is recommended that, for IEE-13 bus test system best result is gotten with four-DG unit while, minimum penetration is achieved with a single-DG unit and for maximum penetration, six-DG units is used. For the IEE 123-bus test system, best results were obtained when a single-DG unit was used while using eight-DG units can be used for maximum penetration.	[40]
30	Active power compensation in a Photovoltaic system	Normalized Laplacian Kernel Adaptive Kalman Filter (NLKAKF)-based control technique and learning based incremental conductance (LIC) maximum power point tracking technique.	The overall performance of the system was found to successfully satisfy the objectives of the developed techniques and the IEEE-519 standard.	The proposed technique computational burden is low and its control is instantaneous hence making it suitable for high-frequency system.	[41]
31	Mitigation of load and photovoltaic output fluctuations in photovoltaic power system	A predictive AGC model	Results indicated that the system controlled by the proposed method produced the expected dynamic performance.		[42]
32	Reactive power compensation, load balancing, as well as low order current harmonic mitigation	A three-phase 100 kVAR energy quality regulator (EQR) based on a three-leg four-wire volt- age source converter	Results showed that the EQR was able to perform the compensation functions as expected	The research on the appropriate system compensation unit and method for the obtainment of control variable under time delay remains a research concern.	[43]
33	Reactive power compensation in a 4-nodes distribution system	A combination of transformer tap-changer, substation capacitors, feeder-switched capacitors and distributed generator	The results obtained for different tap settings of the transformer showed that their technique is effective.	In order to maintain the bus voltages and keep the system losses within acceptable bounds, effective coordination of the transformer tap ratio, compensation	[44]

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				equipment, and excitation of the distribution generator is required.	
34	Active power compensation and harmonics current suppression	Hybrid Static VAR Compensator (SVC)	Their simulation results demonstrated that this technique could compensate for all power quality problems.	The use of proposed scheme will cause to reduce significantly the initial investment cost of compensation system.	[45]
35	Improvement of system stability and voltage compensation	A communication-free droop control scheme with adaptive voltage compensation	The proposed control strategy improved the response and reliability of the energy storage units, and the bus voltage fluctuation was regulated within 3%.	Results obtained from the proposed compensation controller is very helpful in the application of linear switch reluctant generators (LSRG) power generation systems with high output power fluctuations.	[46]
36	Reactive current provision and series voltage compensations	A converter-based compensation technique	The performance of the compensation methods during power reversal and ac fault were found to be effective.	Grid fault ride-through can also be achieved in systems using converter-based compensation methods with effective grid voltage regulation which can be used in renewable system construction or grid retrofitting applications.	[47]
37	Harmonics alleviation, reactive power compensation, and power factor correction	A composite observer-based control technique	The outcome of their simulation proved that the technique is effective in terms of active power compensation and harmonics alleviation.	Feasibility test for the proposed system is based on simulations. Validity of the proposed system in a real-life case scenario is needed.	[48]
38	Reactive power compensation	Inductive energy storage element via a matrix converter (MC)	Their model was tested on a number of systems and its efficacy was validated.	For further research works, the proposed technique can be extended to for harmonic compensation.	[49]
39	Compensation for voltage sag	Pulse-width modulated ac-ac converter-based technique	Their results showed that during voltage sag, the system supplies the missing voltage to maintain the rated voltage in the power system	The proposed approach can be easily integrated into a distribution transformer supplying critical loads.	[50]

40	Compensation for dynamic reactive power	Mixed-integer nonlinear programming model	Their results showed that energy losses were reduced between 13% and 56% as photovoltaic generators were added with direct effects on the voltage profile improvement.	Future work is recommended to investigate failure and maintenance scenarios in PV systems and converters. Other renewable sources, like as wind power or the contribution of electric vehicles and capacitor banks, could be investigated for inclusion in the model. It is also advocated to add economic elements in order to better design for electric power systems.	[51]
41	Compensation for voltage sag and imbalance	Five-level flying-capacitor VSC technique	The results obtained showed that the DSTATCOM performed very effectively in terms of dynamics and steady-state error when compensating for voltage sags and voltage imbalances.	Cost analysis of the proposed system to ascertain economic feasibility is not presented.	[52]
42	Reactive power compensation	Flexible AC Transmission System (FACTS) gadgets-based technique	Their results showed that the methodology is effective for reactive power compensation	Validity of the proposed system is based on simulations. To further ascertain the feasibility of the proposed system and cost analysis, there is need to implement the proposed system in a real-life case study.	[53]
43	Compensation harmonics	Active Power Filter (APF)	The total harmonic distortion (THD) for the system has been reduced to 4.10 %, 3.62 %, 3.06 %, and 2.33 % in the simulation study with and without battery, respectively	Custom power devices are chosen over passive filters to improve power quality.	[54]
44	Compensation for harmonics	Synchronous reference frame strategy	Their simulation showed good results with the reactive current compensation giving an almost ideal result of approximately unity power factor and harmonic currents getting compensated to a larger extent	The load has a significant impact on harmonic performance. Also, because the inverter can only produce voltages in a time-averaged sense, harmonics might not be properly corrected.	[55]

4. Conclusions

When a voltage, current, or frequency rises over or below the norm, then the problems of power quality arise in any electrical system equipment. Literatures show that the equipment in use often underperforms as a result of such complications. Furthermore, poor power quality causes issues such as voltage sag, swell, interruptions, harmonics, and transients. Thus, it is necessary to fix these issues for the system to operate without loss and efficiently. While, these issues lead to a lot more disruption throughout the entire system, compensation proved to be a viable procedure that moderates these kinds of problems. Consequently, the many compensatory techniques utilised nowadays were presented and reviewed in this paper. Each research paper reviewed evaluated the problem solved, technique used, and results obtained. Then challenges are drawn from each work as recommendations for further investigation

Author Contributions: For this research article; author 1 provided supervision, original draft preparation, review and editing; author 2 contributed conceptualization, investigation and validation of the idea. While author 3 as the main supervisor, endorsed the methodology, original draft preparation and resources for the research work. However, all authors have read and approved the final manuscript.

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