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A Comprehensive Review on Recent Trends in Power Quality Enhancement of Renewable Energy Systems using Custom Power Devices

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***Abstract*—In most of the distribution systems Electric Power Quality plays a major role for commercial, industrial and residential applications. The new concept of advanced power electronic based Custom Power Devices mainly distributed static synchronous compensator (D-STATCOM), dynamic voltage restorer (DVR) and unified power quality conditioner (UPQC) have been developed due to the deficiency in the performance of conventional compensating strategies in order to minimalize the power quality disturbances.**
This work presents a comprehensive review on the various custom power devices which are used in order to improve electric power quality. This paper aims to present an extensive outline on the different possible intelligent controls used with Custom power devices that are connected to renewable energy systems. In this survey a set of innovative technical measures are presented in order to alleviate the key power quality issues and also some future scopes on the same for the benefit of research scholars and industrialists is provided.

***Index Terms*— Power Quality, Disturbances, Distributed Generation, UPQC, D STATCOM, DVR.**

I. INTRODUCTION

In this contemporary era, we are entirely reliable on the electric power which is effective, efficient and prevalent in nature. However, if the quality and continuity of the electric power supply is not attained, the effectual working of the system becomes a challenge. Most of the equipment used in commercial and industrial systems require good power quality and also it has to be uninterrupted. Therefore, the quality of electric power is very significant. A lot of recent advanced trends are available in power electronics through which reduction of these issues in a power system is possible and reasonable. One such recent technique is FACTS, through which improvement of power quality and reliability is attainable. Many semiconductor methods are used today in several loads that are constructed of power electronic mechanisms. Some of them to mention are desktop computer systems, adjustable speed drives, SMPS, etc.
An alternative cause of power quality disturbance is the integration of several renewable energy systems which are in trend making a path for eco-friendly awareness, upgraded technology and consistency.
However, these renewable energy sources can be major suppliers of power quality issues which in turn hinders

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the functioning of the equipment. The main concern of a utility system is to provide pure sinusoidal form of electric power and the correct magnitude of current at right frequency at PCC (points of common coupling) to their customers. There are various Custom Power devices.

Some of them are Distribution Series Capacitors (DSC), Dynamic Voltage Restorer (DVR), Distribution Static synchronous Compensators (DSTATCOM), Battery Energy Storage Systems (BESS), Solid State Fault Current Limiter (SSFCL), Active Power Filters (APF), Solid-State Transfer Switches (SSTS), Static Electronic Tap Changers (SETC), Static VAR Compensator (SVC), Superconducting Magnetic Energy Systems (SMES), Surge Arresters (SA), UPS Systems and UPQC.

In this paper, the main focus is on custom power devices like DSTATCOM, DVR and UPQC. Power quality comprises all the features including magnitude of voltage, frequency and waveforms of current in the power circuits. Sometimes, the quality of power may be negotiated due to transient conditions or from the loads that are non-linear in nature. The devices that are mentioned above will regulate the power quality at the point of delivery to customers [5].

IEEE provides an alternate definition "Power Quality is defined as setting up standards for electrical equipment regarding their grounding and powering. These standards are useful for the operation of the electrical equipment, and also are compatible with wiring system and other connected equipment". These circumstances can yield to Power Quality issues which can be modification in voltage, surge in power, voltage and power sags. A very simple approach could be developed to determine what power quality is, it is the precision of features and parameter defined in the system [4]. Power quality difficulties can be fixed in the power system by means of FACTS devices in order to protect the sensitive loads in the power system.

A. Power Quality

When we consider a healthy grid, the power quality is referred to the par level of consumer fulfilment in terms of continual power supply and sustaining voltage, current and frequency within the acceptable limits defined by the grid codes [13]. Any deviation of the above parameters from the acceptable range might result in the mis-operation and failure of both the utility grid and the customer apparatus. Renewable Energy dispersion into the grid might additionally depreciate the quality of power due to the intermittent productivity of the Renewable Energy sources and the various power electronic converters used for their incorporation with the grid [21], [25]. Henceforth, IEEE has led down the guidelines in terms of Power Quality, which is evaluated based on the fluctuations of voltage, voltage and current flickers, and frequency distortion in the grid with Renewable Energy dispersion [18].

These limit the dispersion level of non-conventional sources into the grid. Therefore, mitigation of power quality issue is a major challenge for the smart grids [14]. The commonly experienced Power Quality disturbances, their symptoms, sources of these disturbances, their effects on apparatus and possible mitigation methods are detailed in Table below. Likewise, some of the probable alternate solutions for the mitigation of these issues are comprised in the Table I that might give the basic idea for diminishing of the power quality issues.

II. DFACTS DEVICES

The DFATCS strategies are nothing but flexible AC transmission system (FACTS) devices which are used in the distribution network to regulate the voltage harmonics, voltage magnitude line impedance, phase angle, current harmonics and unbalance loading to uphold the power quality. The DFACTS devices are competent in the improvement of Power Quality in the grid which is incorporated with Renewable Energy penetration [15]. The Performance assessment of various DFACTS devices has been presented in Table II.

The key advantages of DFACTS devices for Power Quality improvement is as follows [14]

• Improved operation of prevailing utility grid.
• Improved flexibility and reliability in the grid with Renewable Energy penetration.
• Improvement of transient and dynamic stability limit of the grid.
• Improved system security.
• Environmentally friendly.
• Improved quality of power supply.

The details related to various DFACTS devices are also provided in the below subsection.

The focus of this paper is restricted to DVR, DSTATCOM and UPQC. Numerous topologies can be comprehended to design a DSTATCOM, DVR, UPQC and it is mainly categorized based on:

1. The type of Distribution system (3P3W and 3P4W),
2. Organization of the power electronic switching strategies,
3. The Nature of converter used.

TABLE I: SYMPTOMS, CAUSES, IMPACTS AND SOLUTION OF PQ DISTURBANCES IN UTILITY GRID [3]– [22]

PQ Disturbances	Details
Voltage sag or dip	**Description**: The RMS voltage level decreases between 10-90% of nominal voltage for ½-cycle to 1-minute. **Symptoms**: Memory loss and data errors, equipment shutdown, decreased equipment life and flickering lights. **Causes**: Faults on the 3P3W or 3P4W utility system, start-up of large motors, inductive loading and switching on the large loads. **Impacts**: Malfunction of embedded based equipment, personal computers, programmable logic controls, and tripping of sensitive equipment. **Solution**: DVR, DSSC, static transfer switch.
Very short Interruptions	**Description**: Complete loss of electrical supply for a few milliseconds to 1 second. **Symptoms**: Decreased equipment life and Flickering lights. **Causes**: Automatic opening and reclosing of protection devices of 3P3W and 3P4W utility network and life of sensitive equipment. **Impacts**: Tripping of sensitive equipment and electromechanical relays and malfunctioning. **Solution**: Machine-Generator set, DSSSC, DVR, static transfer switch.
Long Interruptions	**Description**: Complete loss of electrical supply for a duration greater than 1-2 sec. **Symptoms**: Loss of supply to customer equipment and computer shutdowns. **Causes**: Equipment failure, trees, fire, vehicles striking to lines or poles, failure of protection device and circuit breaker tripping. **Impacts**: Equipment shutdown and sudden damaging occurred in sensitive equipment. **Solution**: DVR, UPQC, Machine-Generator set, DSSSC.
Voltage spike	**Description**: Abrupt rise or fall of the voltage value for a short duration ranging from several microseconds to few milliseconds. **Symptoms**: Flickering lights, data loss and interference. **Causes**: Lightning, lagging PF, capacitor switching and phase faults. **Impacts**: Destruction of electronic components, tripping of sensitive equipment, damage to insulation and winding. **Solution**: DVR, DSSSC, UPQC.
Voltage swell	**Description**: The RMS voltage level increases to 110%-180% of nominal voltage, at the power frequency for duration of ½-cycle to 1-minute. **Symptoms**: Memory loss and data errors, equipment shutdown, decreased equipment life and flickering lights. **Causes**: Switch ON and switch OFF heavy loads, transformers regulation is affected during off-peak hours. **Impacts**: Loss of efficiency in electric rotating machines. **Solution**: DSVC, DSTATCOM, DVR, UPQC.
Harmonic Distortion	**Description**: Superposition of various sine waves into distorted waveform with different phase, magnitudes and multiples of power frequency. **Symptoms**: Electrical equipment/wiring overheated, the decreased performance of the equipment, improper operation of relays. **Causes**: Arc furnaces, welding machines, weak AC grid, non-linear loads, integration of renewable energy sources and rectifier. **Impacts**: Increase neutral current, nuisance tripping of thermal protections, mal-operation of sensitive equipment, overheating. **Solution**: Active and passive filters, multi-pulse configuration.
Voltage Fluctuation	**Description**: Voltage oscillations with amplitude modulation at a frequency of 0 to 30 Hz. **Symptoms**: Dim or bright lights, speed variation of dynamic loads, overheating of equipment and reduced life of the equipment. **Causes**: AC drives, unbalanced loads, inter-harmonic current components, welding and arc furnaces. **Impacts**: Flickering of lighting, fluorescent and incandescent lamps. **Solution**: DSVC, DSTATCOM, DVR, UPQC.
Voltage Unbalance	**Description**: Unevenness in voltage magnitude with varying phase angle. **Symptoms**: Overheating of equipment, reduced efficiency and speed variation in motors. **Causes**: Large 1-phase loads mainly due to the furnaces load, traction load, unbalanced loads and location of grid-tied RESs. **Impacts**: 3-phase induction machines, overheating in motors and life of the equipment. **Solution**: DSVC, DSTATCOM, DVR, UPQC.
	Solution: DSVC, DSTATCOM, DVR, UPQC.
Under voltage	**Description**: A condition in which the voltage reduces below the rated value of the power system equipment. **Symptoms**: Dim or bright lights, equipment shut down, reduced efficiency, distortion and malfunctioning. **Causes**: Heavy network loading, loss of generation, power factor variation, lack of Var support. **Impacts**: All equipment without backup supply facilities shut down in this condition. **Solution**: DSSSC, DSTATCOM, DVR, UPQC.
Other possible solution	Proper earthing of equipment, energy storage systems, network equipment and design, online or hybrid UPS [17].

TABLE II: PERFORMANCE ASSESSMENT OF VARIOUS DFACTS DEVICES

Attributes	DFACTS devices for PQ improvement			
	IPQC	DSSSC	DSTATCOM	UPQC
Reactive power compensation	Good	Poor	Best	Best
Harmonic suppression	Adjustable	Adjustable	Adjustable	Adjustable
Resonance	No	May exist	No	No
Load balancing	Good	Good	Best	Good
Transient stability	Good	Good	Better	Best
Steady state stability	Good	Good	Better	Best
Voltage control	Good	Good	Best	Best
Power rating of converter	Small	High	High	Small
Number of switches	9-12	6	6	12
Overall cost	Medium	Low	Low	Medium
Performance level in hardware design	Good	Good	Better	Best

The features, topologies, and characteristics of DSTATACOM, DVR, UPQC are explained in the following sections.

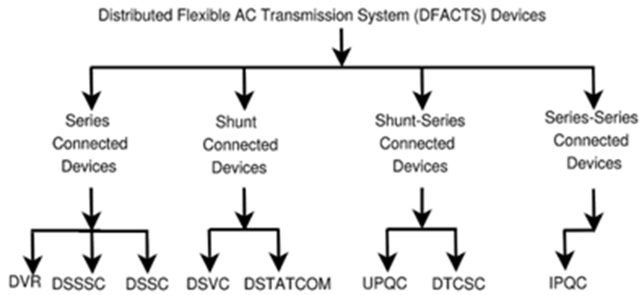

Figure1: Classification of DFacts Devices

A. Dstatcom Operational Mode & Topography:

A DSTATCOM is a device which is connected in shunt with the distribution system at the point of common coupling through a coupling transformer; where in the distribution system consists of unbalanced and nonlinear loads and is shown in figure below.

Initially, the DC input received from storing element is converted into AC and later this is injected into system to compensate the unbalanced system voltage [11]. This complete process is under the control of DSTATCOM. By this means, the Voltage Source Inverter compares the injected voltage and the line voltage, thereby providing the required amount of balance during variations like lagging/ leading voltage [10-12]. For example, if the voltage produced by the of the inverter is larger than the supply voltage, the DSTATCOM functions in capacitive mode and thus generates reactive power or it functions in an inductive mode by absorbing reactive power from the system [13-15]. Hence the main function of the function of DSTATCOM is to supply the reactive power as per requirement to the system in order to regulate the voltage at the point of common coupling.

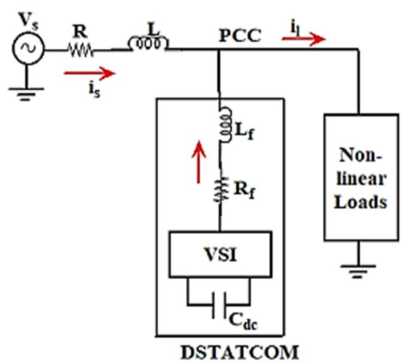

Fig. 2: Schematic arrangement of a DSTATCOM

B. Dynamic Voltage Restorer(DVR) Operational Mode & Topography

The various DSTATCOM topologies are presented in the table III.

DVR consists of an Energy storing Element and a controller scheme, with a Voltage Source Converter (VSC) connected in series with grid through a boosting injection transformer.

Unlike DSTATCOM this is connected in series with the system. The series voltage from the VSC is injected with the help of the converter, each time the system is subjected to a fault or a low voltage condition. This series injected voltage will recompense the system voltage. Therefore, the DVR uninterruptedly looks after the supply voltage and compares it with the reference AC supply voltage, and later it provides the desirable controlled voltage to recompense the voltage fluctuations. The schematic arrangement of DVR is shown below.

Hence the dynamic voltage restorer plays a major role in compensate the voltage sag or voltage swell issues which are major power quality issues that might be most commonly occurred whenever a renewable energy source has been incorporated into the grid at the distribution side.

This compensator mainly is used to regulate the voltage conditions whenever there is a fluctuation due to integration of Non-Conventional DG where as DSTATCOMS are used especially when renewable sources like Wind turbines are integrated into the grid because they can compensate the reactive power fluctuations which are a major concern in DFIGs. The DVR topologies are presented in the table IV.

TABLE III: CLASSIFICATION AND TOPOLOGIES OF DSTATCOM

3P3W	
Non-Isolated	
Topologies	Description
3 leg VSC [16-17]	• Three vertical branches with 2 switches on each leg with a common capacitor. • Number of switches=6. • The mid-point of each leg is connected through an inductor to the supply system.
2 leg VSC with split capacitor [18]	• Two vertical branches with 2 switches on each leg and a split capacitor is used as a third branch. • Number of switches=4 • The mid-point of each leg is connected through an inductor to the supply system.
Isolated	
Three single phase VSC Topology [19]	• Three separate h-bridge VSC is used provided with a transformer individually with a common capacitor. • One terminal end of the primary winding of the transformer are connected to the supply where other three ends are interconnected. • All the secondary winding terminals are connected to the centre of each leg.
Isolated 3 leg System [20-21]	• Three vertical branches with 2 switches on each leg with a common capacitor. • Number of switches=6. • The VSC is connected to the supply system through a start-delta transformer.
Isolated 2 leg system [22]	• Two vertical branches with 2 switches on each leg and it uses a split capacitor. • Number of switches=6. • The VSC is connected to the supply system through a start-delta transformer.

3P4W	
Without Transformer	
Four leg VSC [23]	• Two H-bridge VSC with a common capacitor is used. • Centre point of each leg is connected to the supply system through an interfacing inductor. • It is used for neutral current compensation.
Three leg VSC [24-25]	• Three legs having two switches on each leg is utilized and are interfaced to the system through an inductor • Number of switches =6 • The Three leg VSC is implemented with ➢ With split capacitor ➢ With filter ➢ With neutral at DC point
With Transformer Non-isolated	
3 leg VSC [16,26, 27,28]	• Constructed utilizing Three vertical branches with 2 switches per branch and one common capacitor. • The VSC is connected to the system using an inductor. • The three leg VSC utilized 4 types of transformers and they are ➢ Zig-zag transformer ➢ Star/Delta transformer ➢ Star/Hexagon transformer ➢ T-connected transformer • The 3 phases and neutral of the transformer is connected to three-phase and neutral of the supply.
2 leg VSC [29-31]	• Constructed utilizing two vertical branches with 2 switches per branch. • The VSC is connected to the system through an interfacing inductor and it utilizes a split capacitor. • The two leg VSC utilizes the following 4 types of transformers. • Zig-zag transformer • Star/Delta transformer • Star/Hexagon transformer • T-connected transformer • The 3 phases and neutral of the transformer is connected to three-phase and neutral of the supply.

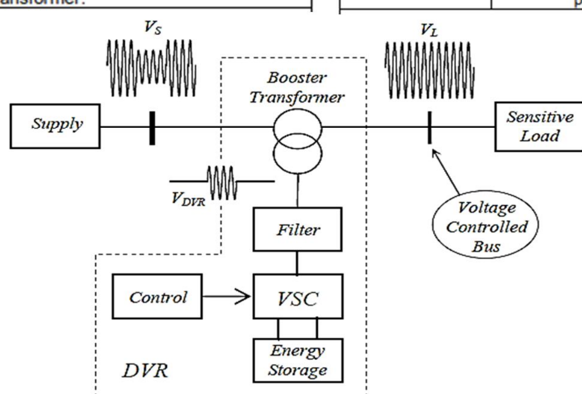

Figure 3: Schematic arrangement of DVR with Constant DC link Voltage (Filter)

C.UPQC Operational Mode & Topography

A Unified Power Quality Conditioner (UPQC) comprises of a series and a shunt controller with a DC link Capacitor connected between the two controllers. The series controller can be sued as a series compensator to regulate the

TABLE IV: VARIOUS TOPOLOGIES OF DVR

Energy Storages	
Without Energy Storage	
Topologies	Description
DVR with no Energy storage [51]	• Here the incoming current will be taken from the shunt converter which is connected to the grid.
With Energy storage	
Constant DC link Voltage [51,52]	• This is basic topology and it employs with the double conversion system
Variable DC link Voltage [51,52]	• It employs with the series converter, DC capacitor or battery bank for energy storage.
Inverter Topology (Multi level Inverters)	
Diode Clamped [53]	• Components required for 3-phase-5 level • No. of IGBT required – 24 • No. of Diodes required – 24 • No. of Clamping diode required – 18 • Here the maximum output voltage which can be obtained is half of the input DC voltage. To overcome this drawback, switches, diodes, capacitors should be increased.
Cascaded H- Bridge [54-55]	• Components required for 3-phase-5 level • No. of IGBT required – 24 • No. of Diodes required – 24 • It reduces the overall harmonic component. It can avoid the unbalance DC link voltage problems when compared with the other topologies.
Flying Capacitor [53,56]	• Components required for 3-phase-5 level • No. of IGBT required – 24 • No. of Diodes required – 24 • Flying Capacitor required – 18 • Here the voltage control is based on the closed loop control scheme.
3- phase Inverters	
3-Phase 4-line Half bridge [57]	• No. of switches required 6. • Large DC capacitor is required. • Neutral point of transformer is connected with the Neutral point of DC capacitor.
3-Phase 4-line bridge [58-59]	• No. of switches requires 8. • Small capacitance is required. • Neutral point of transformer is connected with the Neutral point of fourth Leg.
3-Phase H bridge [59]	• No. of switches required 12. • Small capacitance is required. • It combines the 3 relatively independent full bridges to output 3 phase voltages and there will be no coupling within 3 phases. It has the best ability to compensate the voltages.
3-phase DVR with Split Capacitor [60-61]	• No. of switches required 6. • In this all the phases will operate individually for this it needs the two extra capacitors.
3-phase Push Pull Inverter [61]	• No. of switches required 6. • In this method injection voltage is calculated and magnitude of load and voltage value is restored to nominal value.

voltage and the shunt controller can be used to provide shunt compensation to regulate the current and also in turn regulate the reactive power but during the process of regulation, the rating of the DC link capacitor must be the same for both series and shunt controller.

The UPQC is a new comprehensive fusion filter arrangement of compensators and it is recognized as a multi-functional power conditioner used to recompense for the various disturbances in voltage, regulate voltage variations and also protect the electrical distribution grid from the entry of hazardous harmonic currents.

The shunt compensator can generate or absorb reactive power at the point of common coupling. The shunt compensator is connected with the distribution grid to control the various parameters of line.

Hence it can be inferred that an UPQC has a combined operation of a Distribution Static Compensator (DSTATCOM) and Dynamic Voltage Regulator (DVR) together. So, whenever there is a requirement of series and shunt compensation simultaneously at the same time the UPQC comes into picture.

The UPQC topologies are presented in the table V.

III. CUSTOM POWER DEVICES AND RENEWABLE ENERGY SOURCES

Renewable Energy based Distributed Generation paves the path to enhance the reliability but decreases the power quality of the system most of the times through the inverters. This issue or hurdle can be overcome by using custom power devices mainly UPQC rather than DSTATCOM or DVR to integrate the Non-conventional DG into the distribution grid. However appropriate control of the DC link Capacitor Voltage of the UPQC enhances the dynamic stability of the power system during any disturbances.

In [38], a hybrid DG comprising of fuel cell and DFIG-based wind energy systems are integrated with a weak grid by means of the UPQC. In [37], the UPQC is utilized for the integration of a wind energy system with enhanced Power Quality, the Firefly algorithm is utilized to improve the control pulses with the help of a machine learning a recurring neural network for working out the optimization constraint. In [28], The DSTATCOM of the solar PV-UPQC accomplishes double purposes such as recompensing the reactive power despite the fact of supplying active power from the PV array into the grid. The DVR of the Solar PV-UPQC diminishes the voltage sags and swells.

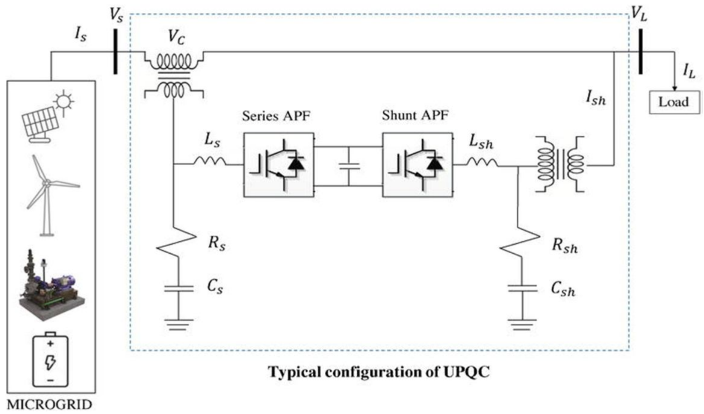

Figure 4: Schematic arrangement of UPQC with DC link Capacitor and filters

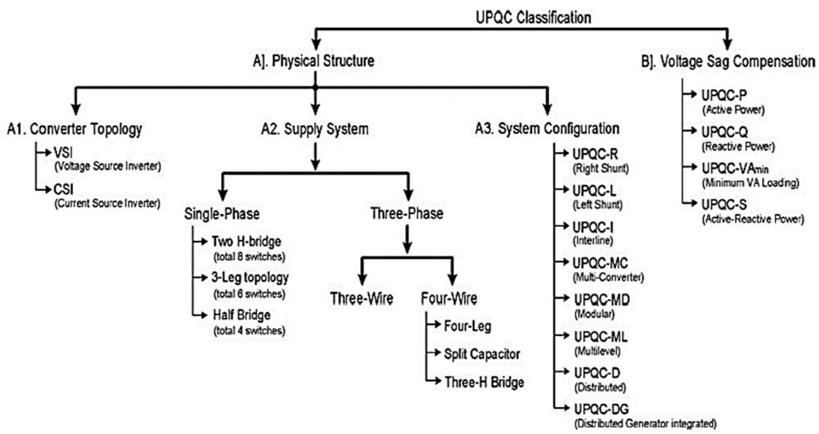

Figure 5: The classification of UPQC

TABLE V: UPQC TOPOLOGIES BASED ON CONFIGURATION

Topology	Description	Ref.
Right Shunt UPQC (UPQC-R)	• A DVR is connected in series with the AC mains and the DSTATCOM near to the load.	[3]
Left Shunt UPQC (UPQC-L)	• A DVR is connected on the load side and DSTATCOM near to the source.	[30,31]
Interline UPQC (UPQC-I)	• A DVR is linked with one of the feeders in series and DSTATCOM is connected in parallel with the second feeder. • It can handle real power flow between two adjacent feeders. • This arrangement only mitigates the current-related PQ problems effectively on the feeder whereas, since the DSTATCOM is connected, the voltage related PQ problems only occur on the feeder to which the DVR is connected.	[32]
Multi-Converter UPQC (UPQC-MC)	• An additional DC Source/VSC is connected to the DC- Link. • It shares real power between two adjacent feeders which are not connected. • It only mitigates the current-related PQ problems effectively on the feeder, whereas, since DSTATCOM is connected, the voltage related PQ problems occur only on the feeder to which the DVR is connected.	[33–35]
Modular UPQC (UPQC-MD) & Multilevel UPQC (UPQC-ML)	• The VSC consists of numerous bridges connected in a cascade. • The DVRs of all cells are connected in parallel while DSTATCOMs are in series to form a UPQC-MD. • Multilevel converters are used for the UPQC-ML in a medium voltage distribution system.	[36–40]
Distributed UPQC (UPQC-D)	• The series transformer neutral of the DVR is utilized as a neutral for the 3P4W load. • The neutral current flowing toward the injecting transformer neutral is compensated by adding the fourth leg of the DSTATCOM to the existing 3P3W UPQC while the voltage of the transformer neutral point is retained at zero.	[41]
Distributed Generators UPQC (UPQC-DG)	• The UPQC is integrated with the DG to the grid. • The DG is connected to the DC-link of UPQC. • Power is supplied to the main grid via the DSTATCOM.	[42–48]

TABLE VI: UPQC TOPOLOGIES BASED ON THE TYPE OF SUPPLY SYSTEM

Topology	Highlighted Aspects
Single-Phase Two-Wire (1P2W)	• DVR and DSTATCOM are isolated from each other by a bidirectional DC/DC-isolated converter and a high-frequency transformer. • The power transfer can be controlled by adjusting the voltage phase shift between two inverters.
Three-Phase Three-Wire (3P3W)	• In high voltage applications, the isolation transformer is used to isolate the DSTATCOM.
	• Ripple filters are connected across both the DVR and DSTATCOM to reduce the switching ripples of the output.
	• In the case of 3P3W with an additional star–hexagon/T-connected transformer, neutral current mitigation is possible only if the voltages across these transformers are sinusoidal.
Three-Phase Four-Wire (3P4W)	*Split Capacitor (2C):* • The neutral wire is connected at the mid-point of the capacitor which is at zero potential. • The equal voltage across both capacitors avoids a circulating current. • An additional control loop is added to maintain the DC-bus capacitor voltage regulation.
	Four Leg (4L): • The neutral current load is compensated by an additional leg having two semiconductor switches.
	Three H-Bridge (3-HB): • Three units of single-phase H-bridges are connected to the same DC-bus of the UPQC.
	• Without affecting its compensation capability, the UPQC works with reduced DC-link voltage as well as helping to fulfill the DC-link voltage requirement of the DSTATCOM and DVR.

TABLE VII: COMPARISON OF VARIOUS CUSTOM POWER DEVICES

Factors	DSTATCOM	SVC	DVR	UPQC
Rating	Low rating	Low	High rating	Higher ratings are available
Speed of operation	Less than DVR	Less than DVR	Fast	Faster
Compensation method	Shunt compensation	Shunt	Series compensation	Both series and shunt
Active/reactive power	Reactive	Reactive	Active/reactive	Both
Harmonics	Less	Less	Much less	Least
Problems addressed	Sag, swell	Sag, swell	Sag, harmonics, fluctuation, swell	Swell, sag, harmonics, transient, unbalance and flicker
Cost	Normal	Average	High	Higher
Complexity	High	High	High	Higher

IV. CONCLUSION

This paper gives a complete survey or review of the various custom power devices, their operation and topologies. The necessity for renewable Energy DG remains to rise at a rapid proportion, although the strong-growing Power Electronic Converter technology makes it probable to incorporate the Renewable Energy DG with the grid.

The UPQC is capable of recompensing for all sorts of source voltage and load current Power Quality complications laterally with the incorporation of RES-DG with the main grid. In Comparation with all the topologies, it can be concluded that the UPQC-DG, UPQC-MC, and UPQC-ML play a significant role in the power system during the integration of RES-DG with the grid.

Renewable energy (RE) Distributed Generation integration with the electrical utility grid is growing day by day and also it affects the quality of supplied power. The weather situations such as intermittent solar insolation and wind speed fluctuations affect the power output of the non-conventional sources. The application of custom power devices in Renewable Energy Distributed Generation based power system is essential to be explored as the custom power devices may be an effective alternative solution for these complications.

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