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Research paper

Recapitulation of various topologies and control strategies implicated in dynamic voltage restorer (DVR) for power quality improvement

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Abstract

The fundamental desire of any power-driven industry is superior power quality of electrical supply for optimum exploitation of resources and smooth operation of equipment. However, some crucial problems such as sags, swells, harmonics and interruptions are documented as power quality issues. Out of those voltage sags and swells are generally found and take in a severe impact on the electrical equipment and thus ought to be compensated at an earliest to shun any mal-operation or crash. As an imperative solution to mitigate the voltage issues a custom power device (CPD), dynamic voltage restorer (DVR) is unanimously acquired. The DVR is a prominent CPD apparently recommended in the literature for the compensation of voltage sag and swell with a pro of active/reactive power management. A bulk vol-ume of literature reported on different configurations of DVR and different control technique utilized in it. This paper envelope detailed review on different feasible power circuit topologies and control techniques of DVR to anticipate power quality problems. The informative stuff coated in it articulates choice of control technique and power circuit ensuring the most advantageous performance of DVR in satisfy-ing the required quality of supply. Also, this paper delivers the valued information for the investigator of this province.

Keywords:*DVR; Power Quality; Compensation Technique; Transformer-Less DVR; Direct AC/AC Converter; IDVR; Solar PV Based DVR.*

1. Introduction

Power quality is of huge importance in all contemporary environments where electrical power is concerned. Quality of service fetched to consumers is extremely subjective by power quality problems. These problems were sorted by five major events; sags, swells transients, interruptions and harmonics. These events can affect the quality of service, which results in economic losses to both service provider and customers [1].Due to the deregulation of the electric power market, power quality becomes a major parameter of concern to attain a higher price per unit, to increase the profits [2]. The prevalent use of equipment sensitive to voltage variance has made industrial applications more susceptible to voltage sags and voltage swells. Among these, the sags appeared as a top [3]. Voltage sags are able to source unacceptable operations and eventually tripping of industrial equipment, followed by loss of time and production, or damage equipment, which might be a reason of significant economic losses [4-5]. Here, the two common approaches to mitigate voltage disturbances either make sure so as to industrial equipment is less reactive to these disturbances, allowing it to ride-through [6] or fix a custom power device (CPD) to counteract the disturbances at the customer end, a device such as Dynamic Voltage Restorer (DVR) is used for doing so. It is one of the most proficient custom power devices, which is used to regulate voltage and mitigate voltage disturbances in any power distribution system. The DVR restore the load voltage after the incident of voltage disturbance by introducing active and/or reactive power into the distribution feeder [7-8].This paper will put an insight on various power quality problems and will introduce DVR with different power circuit and control techniques for mitigation of voltage problem.

2. Power quality

Power quality issue manifests itself as the variation from predefined values of voltage, current or frequency, resulting in failure/mal-operation of utility or customer equipment [2].

2.1. Power quality issues

Some issues associated with power quality are tabulated in table 1with their different causes, effects and example in terms of wave shape [1-2], [4-6], [8-12].

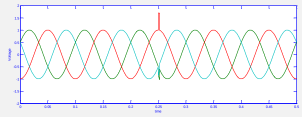
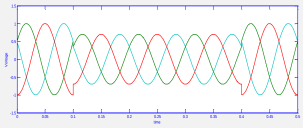
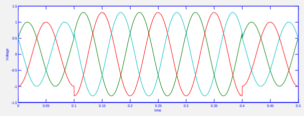
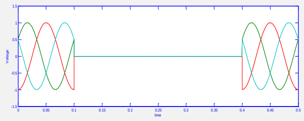
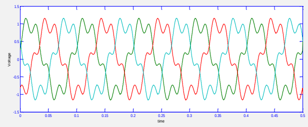
2.2. Solutions for power quality improvement

The custom power devices are offered to compensate above power quality issues mentioned in table 1. These devices are chosen on the basis of parameters such as control over harmonics, compensation of active and/or reactive power and voltage/current disturbances. Some of these devices are listed as:

- Battery Energy Storage Systems (BESS)
- Solid-State Transfer Switches (SSTS)
- Super conducting Magnetic Energy Systems (SMES)
- Uninterruptible Power Supply (UPS)
- Static VAR Compensator (SVC)
- Unified power-quality conditioner (UPQC)
- Distribution-STATCOM (DSTATCOM)

- Dynamic voltage restorer (DVR)

Table 1: Power Quality Issues, Its Causes and Effects

Power quality issues	Characterization	Causes	Effects	Example
Transient	It is a sudden, non power frequency change in steady state condition of voltage.	Lightning on the feeder, Turning ON or OFF of large machine, Back to back capacitor charging.	Tripping of equipment, part failure, process error, information loss, and mandate hardware reboot,	
Voltage sag	It is decrease in 0.1 to 0.9 pu in rms voltage at the power frequency for durations from 0.5 cycle to 1 min	Starting up of large Machine, Energization of heavy loads, Erroneous VAR compensation, Any faults on the transmission or distribution feeder	Faint lights, dwindling display, Apparatus shutdown, Memory crash	
Voltage swell	It is an increase in 1.1 to 1.8 pu in rms voltage at the power frequency for durations from 0.5 cycle to 1 min	Charging of a large capacitor bank, Switching down of a large load, Wrong VAR compensation.	Bright illumination, Data error, Racing or flashing of the digital clock	
Voltage interruption	It is when the supply voltage decreases to less than 0.1 pu for a period of time not exceeding 1 min	Faults (Short circuit), Equipment malfunction, Insulator failure, Lightning, Control failure.	Equipment trips off, Programming lost, Computer shut down, Disk drive collapse	
Harmonics	These are integral multiples of some fundamental frequency that, when added together, results in a distorted waveform	IT apparatus, Fluorescent lights and any non linear load such as variable speed drives (VSD), Electro-Magnetic Interference (EMI) from the electrical device, Switched mode power supplies (SMPS).	Line current raises, Higher losses in transformer, overheating of neutral wire which leads to shorter equipment life, malfunctioning of meters.	

Among all DVR is the technically advanced and inexpensive voltage sag/swell mitigation device in distribution systems. Additionally DVR alsoperformsreactive power control and harmonic compensation. Advantages of DVR over these are as follow [13-22]:

- SSTS only switch load to a healthy feeder from faulty feeder. SSTS does not regulate load voltage.
- The DVR is still favored over SVC only because of capability to control the active power flow whereas SVC only controls the reactive power flow.
- The DVR has high power capacity compared to the UPS and SMES. DVR has plentiful benefits over UPS and BESS like less price, high power, little losses and maintenance.
- The size and price of DVR lesser than DSTATCOM and UPQC.

3. Dynamic voltage restorer (DVR)

The DVR is connected in series with the distribution system as shown in Fig. 1, which is employed to inject an appropriate voltage of required magnitude, waveform and frequency through an injection transformer when voltage sags or swells is detected [23-24].This is achieved by means of the injection of active/reactive power by DVR circuit [25].

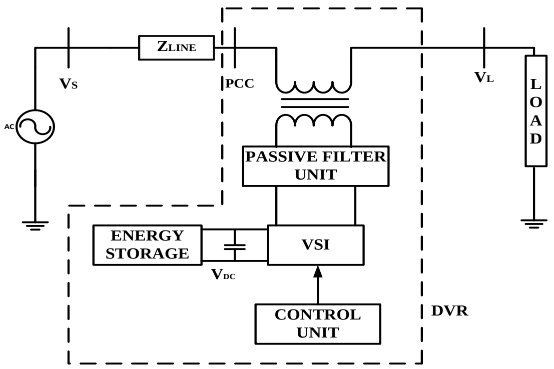


Fig.1: Basic Configuration of DVR.

4. DVR placement in distribution system

The intention of DVR is to protect one or more than consumers from any voltage disturbance, for this DVR can be often installed in Medium Voltage (MV) distribution system to protect group of consumers or in Low Voltage (LV) distribution system for a single consumer.

4.1. LV distribution system

In the four-wire LV distribution system the DVR must secure small impedance for zero sequence components [26-27]. In this arrangement a separate DVR is placed before every sensitive load for this a low rated DVR is adequate.

4.2. MV distribution system

In the three-wire MV distribution system nearly all countries utilize a single DVR topology because it is simple to control as there is absence of zero-sequence component [26-27]. In this arrangement a single high rated DVR is installed for the group of consumers to compensate the voltage disturbances.

5. Power circuit of DVR

In fundamental power circuit of DVR, contains an injection transformer, a voltage source inverter, a harmonic filter, an energy storage device (power source) and a bypass switch.

5.1. Injection transformer

The intention of the injection transformer is to attach the DVR in series with the distribution system in which voltage is to be injected. The injection transformer raises the magnitude of voltage supplied by VSI up to desired level; additionally it isolates the DVR circuit from distribution system [28]. When DVR is employed for single phase, one single-phase transformer is connected and for a DVR of three phase system, three single-phase transformers or a single three phase transformer can be set either in delta/open or star/open configuration.

5.1.1. Delta open configuration

If upstream transformer of distribution feeder is in delta-star configuration, during earth faults on the higher voltage level zero-sequence voltages will not travel through the transformer. Consequently, restoration of only positive sequence and compensation of negative voltages are necessary [29]. Hence, a delta-open injection transformer as showing in Fig. 2 can be used in DVR's power circuit. This configuration maximizes the utilization of DC link voltage [30].

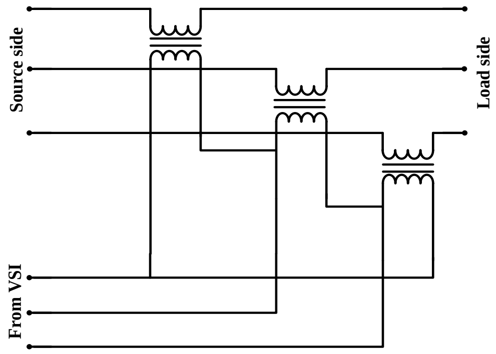


Fig. 2: Delta Open Configuration.

5.1.2. Star-open configuration

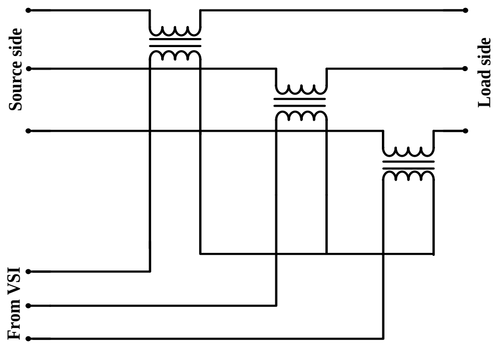


Fig. 3: Star Open Configuration.

If the upstream transformer is an earthed star-star configuration, then zero sequence voltages must be compensated [29]. For this case, a star-open injection transformer as shown in Fig. 3 is employed [31].
The transformer ratio can be calculated to have utmost exploitation of the converter. The injection transformer rating is a key aspect when expecting better performance of DVR, since it confines the maximum compensation voltage of the DVR [32], if the transformer is under rated the injected voltage might saturate the transformer core and effect in inappropriate function of the DVR. This difficulty can be conquered by an over rated transformer, though this will increase the overall volume and price of the DVR [33].

5.2. DC-link and energy storage devices

The DC-link and energy storage device offers the true power for DVR operation for the duration of sag compensation. The required DC voltage for inverter operation can be taken from an auxiliary supply (topologies accompanied by energy storage) or grid itself (topologies without energy storage).

5.2.1. Topologies with energy storage

If the power grid is weak then the auxiliary source of DC supply is used. In this class, constant DC link voltage or variable DC link voltage converter is employed. Flywheels, batteries, superconducting magnetic energy storage (SMES) and super capacitors come in the category of auxiliary DC supply system.

5.2.2. Topologies with no energy storage

In grid supported topology, a strong grid provides voltage on supply side or load side to supply required voltage to the DVR, for this method AC/DC/AC converter such as Supply Side or Load Side Connected Converter is employed. If the topologies are evaluated by some measures like performance, expenditure, system and control intricacy, benefits and drawbacks they can be arranged as [34-37]:
1) Grid supplied: Load Side Connected Converter
2) Auxiliary supplied: Constant DC Link Voltage
3) Auxiliary supplied: Variable DC Link Voltage
4) Grid supplied: Supply Side Connected Converter

5.3. Voltage source inverter (VSI)

VSI is a power electronics converter consists of DC storage. The basic function of the VSI is to change the dc voltage supplied by the DC energy storage /dc-link into a sinusoidal voltage of desired frequency, amplitude and phase angle. The VSI used in the DVR circuit can be two-level (conventional) or multilevel (MLI).

5.3.1. Conventional two level inverter

The pulse width modulation (PWM) based two-level inverter is the trendiest type of inverter used in DVR as it is easy to implementation of the PWM and it is less costly than MLI [28].

5.3.2. Multilevel inverter

The multilevel inverter has good characteristics for harmonic control, it produces fewer harmonics compare to conventional and can operate in higher voltage levels [38].The common topologies of multilevel inverters are neutral point clamped (NPC) MLI, flying capacitor MLI and cascaded H-bridge (CHB) MLI which used in the DVR structure [38-42], though the most trendy is cascaded H-bridge (CHB) MLI. When a DVR circuit uses a step up voltage injection transformer, a VSI with a low voltage rating is sufficient [41].

5.4. Harmonic filter

The passive harmonic filter is generally used in DVR circuit to lessen the switching harmonics generated by the VSI inacceptable level. The PWM technique is employed to control the VSI output, if the modulation index is set under '1', the switching harmonics are usually centered near to switching frequency and multiples of the switching frequency [43]. The harmonic filters can be placed either in low voltage (VSI) side or in the high voltage (load) side of winding of the injection transformer [44].

5.4.1. Low voltage side filter

If a filter is inserted at VSI side, the higher order harmonics are not reached to transformer. In this way it trims down the voltage stress on the transformer. Although there can be a phase shift and voltage drop introduced in the output voltage, which can upset the control strategy [45-46].

5.4.2. High voltage side filter

When a filter is inserted at the load side phase shift cannot take place but harmonics can penetrate into the high voltage side of the transformer, and a higher rating transformer is required[43].On the other hand leakage reactance of the transformer can be used as a part of the filter, which will be supportive during tuning of the filter[47].

5.5. By-pass switch

The DVR is a device which is connected in series with the feeder and due to this it is difficult to guard DVR in short circuit, unable to keep away from interference with the existing equipment. At the time of overload, fault and repair another path for the load current has to be provided. Normally a power electronic switch is used to bypasses the VSI circuit [28].

6. Operation modes of DVR

6.1. Protection mode

The DVR has to be protected from the high current arising due to short circuit on the load. During fault, the DVR is isolated from the distribution system to save from high current using bypass switches as shown in Fig. 4 [22].

6.2. Standby mode (V_{DVR} = 0)

In normal operation the DVR may either set into short circuit operation which is termed as a standby mode or inject little quantity of voltage to conquer the voltage drop and losses on transformer reactance [22], [48].

6.3. Injection mode (V_{DVR}>0)

As sag is sensed by the DVR, it sets up into injection mode, and an AC voltage of required amplitude, phase angle and frequency is inserted in series to the distribution system for voltage regulation [22].

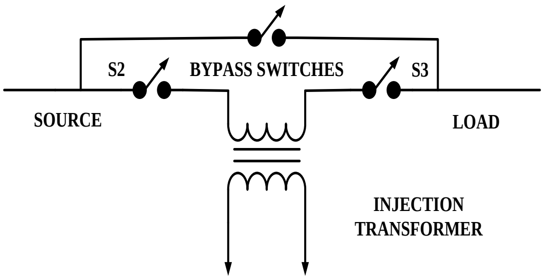


Fig. 4: Mode of Operation

7. Voltage injection/compensation techniques of DVR

7.1. In-phase injection/compensation technique

In this, DVR injected voltage is in phase with the supply voltage, and suggested for the load wherever voltage amplitude is the only parameter of concern i.e. linear load. The required amount of the injected voltage is least; hence voltage rating of the dc storage system/DC link is minimal. The true power is needed for compensation; it cannot fix up the phase angle jump [49-53].

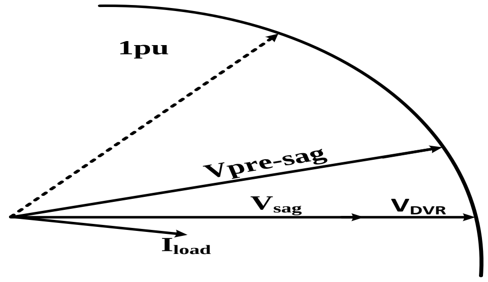


Fig. 5: In-Phase Injection/Compensation.

7.2. Pre-sag injection/compensation technique

In this, DVR keeps load voltage phasor unchanged in relation to that before the sag. For the non linear load; i.e. sensitive to phase angle shoot this technique is suggested. It re-establishes both voltage sag and the phase angle. Furthermore, it avoids any circulating current at the load end. It needs true power when compensating [49-53].

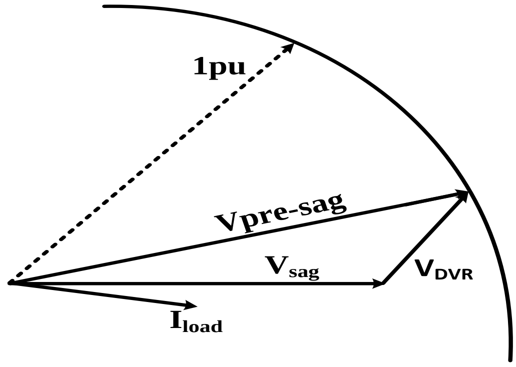


Fig. 6: Pre-Sag Injection/Compensation.

7.3. In-phase advanced/energy optimization compensation technique

In this, DVR voltage advances the load voltage, thus the injected voltage phasor and load current both are at right angles to each other. The basic thought behind the energy optimization technique is to make the true power requirement zero by having the injection voltage phasor at right angles to the load current phasor [49-58]. It utilizes only reactive power for compensation, reactive power is produced electronically within the VSI [57-88], thus high rating of VSI requisite. This method is only suitable for a limited range of sags because all sag cannot be diminished without the true power. Performances of different techniques are tabularized in table 2. Essentially the type of load (linear or non-linear) influences the compensation method.

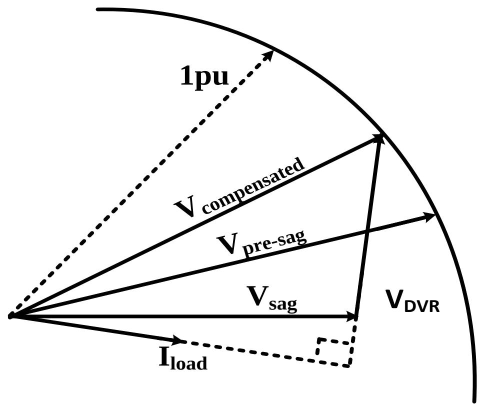


Fig. 7: In-Phase Advanced/Energy Optimization Compensation.

Table 2: Performance of Various Voltage Compensation Techniques of DVR

	In phase	Pre-sag	In phase advanced
Preferred Load	Linear	Non-linear	Linear
Fix up	Only magnitude of voltage	Both voltage magnitude and phase angle	Only voltage magnitude
Rating of power circuit components	Minimum rating of storage device Minimum rating injection transformer	Higher rated storage device Higher rated injection transformer	Higher rating of inverter
Amplitude of injected voltage	Least.	High.	Quite high compared to other two methods
Requirement of Real power	Yes	Yes	No
Requirement of Reactive power	Yes	Yes	Yes
Reliability	Least reliable	Reliable	Least reliable
Results of method	It does not get rid of voltage disturbances totally.	It gets rid of the voltage disturbance totally even if the phase angle jumps of voltage in each phase are different	It does not get rid of voltage disturbances totally

8. Control circuit

In DVR, the aim of the control circuit is to regulate the parameters such as magnitude, frequency and phase shift as per the requirement. Control can be implemented in 3 steps, detection of voltage sag/swell instance, comparison with a reference value and production of VSI gate pulses. Following steps make sure that VSI will generate the output voltage which compensates voltage sag.

8.1. Sag detection techniques

The precise detection of voltage disturbances is required to control the load voltage. To spot the voltage sag, its starting and ending instant, deepness of sag and phase shift some detection techniques are summarized below:

8.1.1. Fourier transform (FT) method

To realize the FT, the orthogonal decomposition of power signals is applied. By applying the FT to each phase of supply, it is possible to achieve the magnitude and phase of each supply waveform. The FT requires one complete cycle to give the exact information on the sag deepness and its phase jump. The realization in real time is feasible [59-61], [65-66].

8.1.2. Phase locked loop (PLL) method

PLL works on each supply phase separately and is adjusted to react to phase angle jumps in the supply quickly. It requires freezing the pre-sag magnitude and phasing angle. It produces the voltage in same phase with the supply voltage and takes time up to half cycle. The realization in real time is more complex [59-61].

8.1.3. Peak value method

Peak value detection is the simplest method of monitoring the peak of the supply voltage. In this comparison of the supplied value with a reference value at every instant is made, a controller can be set to detect sag if there is a divergence more than a specified value. The information of sag depth, start and end time is obtained, and phase shift information is not received by this method. It takes up to half a cycle to get information of the sag depth [59-61].

8.1.4. Root mean square (RMS) method

RMS value detection is an accurate way to detect the voltage sag and its start and end time, but it does not give phase angle jump information. It takes more time to determine the RMS value [62-65].

8.1.5. Space vector control method

This gives the information of voltage magnitude and phase angle shift as well. Three phase voltages V_a, V_b, and V_c are transformed into a two dimension voltage V_d, V_q (magnitude and phase angle) by abc-dq transformation. It is quicker but involves complex controller. It can be easily taken in real time system [59-61].

8.1.6. Wavelet transform (WT) method

WT does better with non-periodic and non-stationary signal. In wavelet analysis method, to sense any change in magnitude and phase shift of the supply phases quickly, a wavelet prototype function, or the mother wavelet is designed. The drawback of this is choice of right mother wavelet for each application, as the associated filter bank coefficients depend on selected mother wavelet. There is also a delay, because of many mother wavelets in the convolution process. The realization in real time system is complicated [59-61], [66-68].

8.2. Control strategies

The VSI control strategy includes two kinds of control: linear and non linear.

8.2.1. Linear control

The linear control used in DVR is feed forward, feedback or composite. The comparison between these controls is tabularized in Table 3.

8.2.2. Feed forward

The feed forward control is the prime choice of DVR system, as it is simple and speedy. It does not measure the load voltage rather it estimates the voltage to be injected from the difference between the pre-sag and during-sag voltages. The downside of this control is the high steady state error [69-70].

8.2.3. Feed back

The feedback control measures the voltage at the load, and the injected voltage is the difference between the reference and actual load voltage. It has the advantage of exact response, but also has difficult design and time-delay [69-70].

8.2.3.1. Composite control

Composite control is a method in the company of grid voltage feed forward and load side voltage feedback, adding up the power of both feed forward and feedback control. If the feedback control inside the composite control is designed to double-loop, it can get better system stability, performance, flexibility with dynamic load and at the same time combined feed forward control can improve the system's dynamic response rate, reduces the time of compensation significantly [70].

Table 3: Comparison of Different Linear Controllers

	Feed forward	**Feed back**	**Composite**
Evaluate for control	Grid voltage	Load voltage	Grid voltage for feed forward Load side voltage for feedback
Reaction time	Fast	Medium	It has power of both feed-forward and feedback both.
Steady state error	Higher	Can be removed	
Transient over shoot	Complex control	Controllable	
Stability	Good	Can be instable	
Switching harmonics effects	Do not reach to the control	Reach to the control	
Compensation of non-symmetrical fault	Achievable but slow	Good	

8.2.4. Non –linear Control

The DVR is a non-linear device, as it has power semiconductor switches in the inverter circuit, so that the nonlinear control is more suitable than the linear control.

8.2.4.1. Fuzzy logic (FL)based control

FL control is an attractive option when accurate mathematical formulations are not practical. When it is applied, the transient overshoot and tracking error of PWM can be considerably reduced. On the other hand, the properties of the FL control are very liable to any change of fuzzy sets shape and overlapping. Hence, the design and performance strongly depends on the skill and knowledge of the designer [70-73].

8.2.4.2. Artificial neural network (ANN)based control

The ANN has learning and self-organizing capability to facilitate improved accuracy by exclamation. It sets up the nonlinear relationship based on input and output, with no the mathematical modeling [29], [70], [74].

8.2.4.3. Space vector pulse width modulation (SVPWM) based control

In SVPWM, a voltage inverter space vector of the switch is adapted to get quasi-circular rotating magnetic field as a substitute of the Sinusoidal PWM, so that superior performance of the switch-over is accomplished in low switching frequency condition. The SVPWM is a superior, computation-intensive PWM method and probably the finest among all the PWM techniques. SVPWM is preferred because of its easier realization and enhanced dc bus utilization [70], [75-77].

9. Recent technological innovation in power circuit of DVR

The conventional DVR topology has some shortcomings such as the high price and spending more energy during long duration voltage disturbance. To conquer such shortcomings DVR with some alterations in operation and power circuit accounted in the literature are explicated below:

9.1. Interline dynamic voltage restorer (IDVR)

The selected energy storage device and compensation technique govern the active power capacity of the DVR for restoration of pre-sag voltage [78].Though, the size and cost of energy storage device limit the capacity, hence the DVR active power injection capability effected. If the necessary active power is taken from adjacent feeder(s), this would cut down the size and price of the DVR, and the arrangement is known as inter-line dynamic voltage restorer (IDVR).In IDVR, several DVRs on different distribution lines share a common DC link, which facilitates active power exchange between these DVRs.

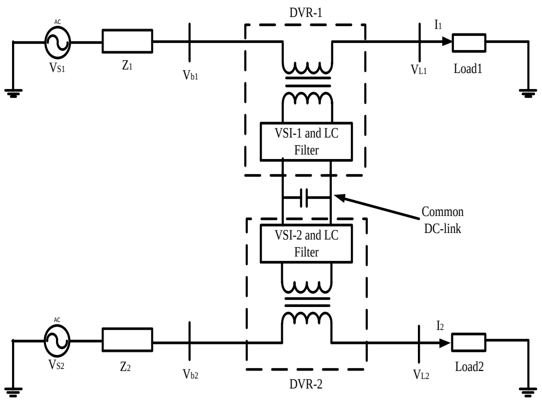


Fig. 8: 2-Lines Inter-Line Dynamic Voltage Restorer (IDVR).

IDVR system, feeders are emanating from different grid substations, so the voltage magnitude of these feeders could be at same or different [79-81]. DVRs in IDVR system works either in voltage compensation mode or in power flow control mode, which means one of them carries out voltage compensation for the period of sag, and the other DVR can replenish energy to the DC-link to maintain its voltage at a specific point. Voltage sag mitigation in both feeders at the same time is not possible with the two feeders IDVR as shown in Fig.8,if active power is fed from DC-link capacitor. To conquer these restrictions, renewable energy sources and/or energy storage device can be coupled to the common DC-link [82-85].

9.2. Transformer-less DVR

The transformer-less DVR has also been accounted in literature for voltage compensation. This gets rid of the cost and weight of injection transformer used in the basic configuration of DVR. There are also some problems such as saturation and inrush currents related to the transformer magnetization phenomenon still after it's judiciously designed. The ride-through capability offered by the conventional DVR with injection transformer and the transformer-less DVR schemes are same for underbalanced three-phase voltage sags, however, during single-phase voltage sag the ride-through ability of transformer-less DVR is just 1/3 that of the conventional DVR[33] [38][86-87].

9.3. Direct AC-to-AC converter based DVR

This gets rid of the need for DC-link. The DVR works on both the topologies: conventional ac-dc-ac (DC-link) conversion and direct ac-ac (AC link) conversion. Conventional ac-dc-ac topology is categorized as to where required dc voltage is provided through a transformer from the grid (source side or load side) via a rectifier [88-89]. Besides the conventional topology, there are a number of topologies have been found for DVR in which direct ac/ac converter without any energy storage elements or DC link [89-92]. Conventional topology generally employs a voltage source inverter (VSI) [40], whereas in ac-ac conversion topologies Matrix Converter [93-95] and Vector Switching Converter VeSC [96-98] are popularly employed.

9.4. Solar photovoltaic based DVR

This topology provides the DC voltage requirement of DVR by solar PV system instead of energy storage device. In the basic DVR topology voltage injection to compensate the voltage sag needs a high capacity DC storage system for this super capacitor, flywheels, batteries, and superconducting magnetic energy storage (SMES) are used. Recently due to trends towards the use of renewable energy a DVR is supported by PV system instead of DC storage system. A PV based DVR topology is capable of handling 10% voltage sags, 190% of voltage swells and outages at a low voltage distribution system [99-100]. For optimal utilization of PV system, a DC–DC converter associated with a maximum power point technique (MPPT) is introduced [101].On the other hand DVR is also finding application where solar PV system is used as Distributed Generation (DG) system to supply small scale loads and to ensure constant
voltage at load point a DVR is inserted in between DG system and sensitive load [102].

Table 4: Pros and Cons of Various Technological Invented Power Circuit of DVR

Recent technological innovation in power circuit of DVR	Pros	Cons
Interline Dynamic Voltage Restorer (IDVR) [78-85]	• The cost of installation can be reduced by the sharing of a common energy storage system. • Economic move to improve multiline power quality. • Compensating long duration deep voltage sags • Reduction in size of dc-link capacitor	• The load’s power factor influences amount of true power requirement. • Renewable energy sources or batteries have to be connected between the common DC link otherwise it is not capable to mitigate the voltage sag by the neighboring feeder if it also experiences the sag at the same time.
Transformer-less DVR [86-87]	• Non linear effects of transformer are removed. • DVR with a low volume, low weight is obtained. • Due to low weight and volume cost is less.	• Convertor control is more difficult. • No. of components is higher. • Protection of power electronic switches is more problematical.
Direct AC to AC converter based DVR[40], [88-98]	• Less cost. • Low weight and size. • Compensation is able to be accomplished for longer duration. • Reduced area of fixing.	• Number of switches is high. • Limited compensation range, in case of deep sag it may not be successful.
Solar PV based DVR [99-102]	• Solar power is contamination free. • Reduces waste and emission. • PV system can operate for several years with small maintenance.	• Photovoltaic cells are expensive. • Solar electricity cannot available at night and is in cloudy conditions. Therefore, a storage system is mandatory. • Solar cell’s output is DC which must be converted into AC.

10. Conclusion

In this article a brief literature review is compiled for DVR configurations, operations and control strategies.DVR proofs as a self sufficient device for normalizing various power quality issues and hence delivering improved quality of power. Various parts of it are explained in brief. By choosing any one of the DVR design we can neutralize or compensate for a variety of power quality problems such as voltage sag compensation and voltage harmonics. Howeverchoice of different controls and power circuits should be precisely made as per the need of operation and its cost effectiveness. To get better performance of DVR, efforts are made on reduced ratings, least power injection, energy savings, reduced parts and losses.

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