Power Quality Issues and their Mitigation Techniques by using DSTATCOM in Microgrid System- A Review

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Abstract - Power Quality is playing an increasingly significant role both at supply and demand sides. With the advent of participation of private player's in distribution systems, the power quality is expected to be the pivotal decisive factor before the consumers. Due to ever growing application of switching devices, the power quality is bound to get deteriorated, at the same time such devices are also prone to malfunction due to poor power quality. The world is driven by the carbon emission to replace the conventional generation by as much renewable generation as possible. The above situation has attracted the attention of researchers to identify and suggest the mitigation techniques of power quality issue's for improving the performance of microgrid containing renewable energy resources. An attempt has been made to comprehensively present a review of the research carried out thus far.

***Key Words*: DVR; Power Quality; voltage sag; voltage swell; Microgrid; DSTATCOM; FACTS.**

1. INTRODUCTION

Microgrids are electricity distribution systems containing loads and distributed energy resources such as generators, energy storage systems or controllable loads that can be operated in a controlled, coordinated way either while connected to the grid or while islanded.

Typical solutions that can be deployed by businesses include onsite generation, energy storage systems, electric vehicle charging infrastructure, uninterruptible power supplies, multi-site virtual power plants, energy efficiency measures, dynamically controlled load and active network management.

A stand-alone microgrid has its own sources of electricity, supplemented with an energy storage system. They are used where power transmission and distribution from a major centralized energy source is too far and costly to operate.[1] They offer an option for rural electrification in remote areas and on smaller geographical islands. A stand-alone microgrid can effectively integrate various sources of distributed generation (DG), especially renewable energy sources (RES).[2]

Control and protection are difficulties to microgrids, as all ancillary services for system stabilization must be generated within the microgrid and low short-circuit levels can be challenging for selective operation of the protection systems. An important feature is also to provide multiple useful energy needs, such as heating and cooling besides electricity, since this allows energy carrier substitution and increased energy efficiency due to waste heat utilization for heating, domestic hot water, and cooling purposes (cross sectoral energy usage).[3]

Electricity for the isolated area is still main issue in the power system research recently [1]-[3]. For that purposes, clean alternative energy sources like small scale hydro, solar, wind, biomass, is necessary [4], especially in the archipelago country like Indonesia. However, the system reliability and the supply continuity are still necessary as the requirement. For this purpose, the smart and controllable small power system for enhancing the potential of renewable energy sources (RES) is necessary. It can be realized using the microgrid concept.

Microgrid usually consists of small generating units, which are vulnerable to severe stability and reliability issues, especially solar, wind, and tidal power plant. They have intermittent characteristic, which the power is fluctuating [5]- [7]. It will directly affect the system frequency and voltage as the power quality indicators. On the other hand, load fluctuation can also affect those power quality indicators [8]. Poor power factor in a microgrid system might be occur from the machine characteristic of RES generation units, an example in doubly fed induction generator (DFIG) which based on induction machine [9], [10]. In addition, the electric power consumption by inductive loads such as motor, TL lamp, solenoid, and transformer [11] can also worsen the power factor.

Power Quality is referred as maintaining near sinusoidal power distribution at rated voltage magnitude and frequency and is an important aspect needed to be addressed in a grid connected microgrid. During the operation of microgrid, presence of switching devices, sensitive and non linear loads can influence the power quality and also on the other hand due to the presence of intermittent DGs like solar energy and wind power may affect the power quality of a microgrid. Therefore, a critical decision is needed to adopt advanced control technologies to decrease the negative effects caused by DG connected grid. Poor power quality will result into poor on-grid electricity pricing especially in a future power quality sensitive market [12].

M.V Manoj e.t al implemented a dual voltage source inverters (DVSI) scheme based on instantaneous symmetrical component theory (ISCT) to compensate unbalance and nonlinear load. With the proposed scheme the reliability of the system increased, reduction in filter size so in cost and better utilization of microgrid power. In [13] an enhanced control structure with multiple current loop damping for unbalance voltage and harmonic compensation in an ac microgrid for power sharing is addressed. In [14] authors investigated a microgrid resonance propagation model, an improved virtual impedance control method with a non linear virtual capacitor and a virtual damping resistor is proposed. The resistive component results in active resonance damping and the harmonic voltage drop on grid side inductor is compensated by the capacitor.

2. MICROGRID SYSTEM

A microgrid is a small scale power system consisting of distributed energy resources such as RES plant, storage, and reactive power sources [15]. Microgrid will become the subordinate of the distribution system or independent as an isolated system.

Microgrid has several advantages which can be summarized in the following aspects:

- Efficiency: lower the distribution system losses and scalable distribution systems.
- Reliability: increase the availability in the distribution side.
- Security: enables monitoring and control in the distribution level.
- Quality: stabilizes power to meet any variety of consumer needs.
- Sustainability: enabling small scale RES generation.

Microgrid can be categorized into two types, that are part of the distribution system or stand alone microgrid. In the first type, the microgrid is connected to the distribution transformer through the PCC. In this configuration, the communication between the microgrid and the distribution system operators is needed. In this type of microgrid, the typical units are solar, wind and hydro plant [16]. In the standalone microgrid which is suitable for remote area, the control will be more complicated since the full controllable generating units are necesarry. The microgrid not only supply the baseload but also during the peak load period. For that reason, storage units and ancillary services are necessary in some microgrids.

3. DSTATCOM

D-STATCOM topology usually consists of a coupling transformer, inverter, and energy storage device as presented in [17]. The topology of the system connected by D-STATCOM to a distribution system, load and small generation unit as presented in Fig. 1.

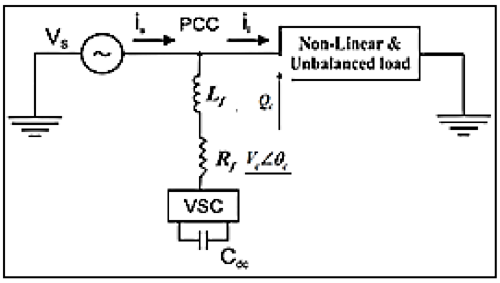

Figure 1. Topology diagram of D-STATCOM.

D-STATCOM can give the extended function of the conventional capacitor bank or Static Voltage Compensator (SVC). The capacitor bank can only support the reactive power at a specific value. D-STATCOM can give the reactive power support by the power electronic technology. If necessary, the active power can also be compensated if the storage is available in the system. However, the installation cost of D-STATCOM is also higher than the conventional capacitor bank.

In addition, the control of reactive power for controlling voltage drop and poor power factor can be set by determining some set points as presented in [18]. Depending also from the typical of the D-STATCOM, the transient support can also be compensated by D-STATCOM. In this type, the D- STATCOM has the ability for compensating faster transient even than SVC . The injected power by D-STATCOM are presented in equations (1) and (2).

$$P_{inj} = V_i(i_d\cos\theta_i + i_q\sin\theta_i) = v_d i_d + v_q i_q \quad (1)$$

$$Q_{inj} = V_i(i_d\sin\theta_i - i_q\cos\theta_i) = -v_d i_d + v_q i_q \quad (2)$$

where i_d and i_q are currents in the dq0 forms representing the direct and quadrature axis. Those variables are control variables representing the injected current of D-STATCOM. It decides the reactive power injected into the system.

For compensating the faster transient even with the flexible support, D-STATCOM has several main components such are voltage source converter (VSC), transformer, ripplefilter and AC inductor as modeled in.

VSC is used for converting the DC input to and AC output voltage for enabling the flexible power flow mode. Transformer is used for balancing the unbalanced load by controlling the neutral current. Ripple filter is necessary to maintain the power quality of the D-STATCOM output.Finally, the AC inductor is useful for minimizing the ripple.

4. ROLE OF CONTROLLERS IN POWER QUALITY ISSUES

Established the mathematical model of PV system and designed a voltage tracking controller based on H∞ control theory. The flexible H∞ control method conveniently achieves dynamic tracking of voltage waveform by detecting instantaneous voltage as compared to the conventional synchronous grid connection method. There is significant improvement in the transition process during grid connection of PV system and redetection in fundamental disturbance caused by PV system to the microgrid. In [6] theory of negative sequence voltage generated from virtual impedance utilized for the compensation of unbalance in voltage. In, a simple fuzzy logic based controller is presented for the control of inverter system and also works well for variable speed wind turbine permanent magnet synchronous generator operation but the steady state error is hard to avoid and may result into small oscillations near the operating point. introduces intelligent solution concept to mitigate the side effect of the double grid frequency voltage ripple on power quality and also the efficiency of single phase grid connected PV system based microgrid. The author proposed a system with three control loops; MPPT control loop, dc link control loop and inverter control loop. It also studies the effect of modified MPPT controller on the system performance. The results obtained shows higher power quality and higher efficiency. Proposed a current controller based on synchronous reference frame comprised of a proportional integral controller and three resonant controllers. With the proposed controller scheme there is no need of extra hardware for the measurement of demand of local current and also the proposed controller can transfer sinusoidal current into the grid despite the presence of distorted grid voltage due to non linear load.[10] proposed a magnetic flux control based novel variable reactor integrated power quality controller. The experimental results verify the validity of power quality controller with novel variable reactor and also it can mitigate the harmonic penetration. In [11], the author suggested a method for deriving proportional-resonant (PR) controller coefficients and structure desired according to transient behavior of AC signal amplitude. In the proposed method AC signal envelope is perceived as DC signal so that its transient behavior can be easily shaped based on approaches utilized in DC system loop while taking zero phase tracking error all the time. The validity of the proposed method is evaluated by simulation results.

5. POWER QUALITY IMPROVEMENT THROUGH FACTS

In [12], the authors utilized DSTATCOM for active power injection and voltage regulation for wind energy system (WES), sliding mode control is used to maintain the power balance at grid terminal during wind variation. In lv(low voltage) microgrid high voltage distortion results in harmonic currents. In [13] a resonant current scheme is employed to track fundamental current and also suppress harmonic current. Two inferences are drawn related to the location of DSTATCOM.

- When DSTATCOM is placed near source regulatingperformance is worse.
- When DSTATCOM is placed at the end of transmissionline regulating performance is best.

In [14] authors introduced an IR technique (Intelligent detection & reconnection technique) in the UPQC for secondary control and also integrated dc link with the storage system. The added advantage of this scheme over the normal UPQC is compensation of voltage interruption in addition to voltage sag, swell, reactive power compensation and harmonics. This technique also allows DG converter to remain connected while voltage disturbance/phase jump. In [15] an improved controller based UPQC is proposed named as UPQC. In addition to providing all the conventional UPQC compensation at load side iUPQC will work also work as STATCOM near the grid side bus. [16] Implemented an SVC using a fuzzy logic based control strategy to mitigate power quality issues identified through the PQ theory based power flow characterization. [17] in this paper, the author proposed a new topology based on double flying capacitor multicellular (DFCM) converter. The advantage of this DVR topology lies in fact that there is no need of any line frequency step up transformer to be connected in medium voltage grid. Also DVR obtains the required active power from energy storage feeding dc link.

6. HARMONIC MITIGATION TECHNIQUES

To improve the quality and performance of the grid harmonic mitigation techniques are very important. The harmonic mitigation techniques are broadly classified as

- passive techniques.
- multi-pulse rectifier techniques.
- Active harmonic cancellation techniques.

In many of the low power industrial applications traditional harmonic mitigation techniques like AC and DC choke are used due to advantage of low cost, reliability and simplicity. Focused on passive harmonic technique to analyze a low distribution network with single and multi unit converters connected to a grid. The study shows that harmonic mitigation depends on grid configuration and also current harmonic mitigation is possible at system level when more number of converters are connected to a grid. In [18] author proposed a reduced d.c link capacitor for three phase power converter called as 'Slim DC link Converter'. In these drives electrolyte capacitor is replaced by small film capacitor. In [20] A. Elrayyah et. al proposed an efficient method to estimate grid harmonics to be used by single phase renewable energy source. In proposed algorithm single phase voltage or current is transformed from stationary reference frame to dq revolving reference frame, this eliminates the need of generating fictitious waveforms orthogonal to measured quanities which will result into lower computation complexity. [21] Implemented a positive sequence phase angle estimation method based on discrete Fourier transform The proposed method has one cycle transient response and is immune to harmonics, noises, voltage imbalances, and grid frequency variations.

Various filters are also used as an attempt to reduce THD or harmonics in microgrids. In [22] shunt active power filter is used for the enhancement of the power quality of a microgrid system at distribution level. To enhance the performance of the shunt active filter, neural learning algorithm technique is used. The performance of the proposed technique and comparison of different pulse generation scheme is verified in the platform of Matlab/Simulink. In [23] pointing the problem of power quality due to the incorporation of renewable sources, a control method with active power filter is proposed. In this work, the power generated by the renewable source is injected to the grid by the inverter (works like shunt active power filter and injects power to the grid). The inverter works in two modes, in mode I, injecting power from renewable source and improving the power quality and in mode II, no power is generated and it acts like a shunt active power filter. In [24] idea to reduce harmonic current using Empirical mode decomposition (EMD) and intrinsic mode regression (SVR) theory based method is proposed and also effectively used in microgrid hybrid active power filter. The harmonic current is split using EMD first and then using SVR module the anticipated values of every harmonic weighted are calculated.

7. CONCLUSION

In this paper an attempt has been made for the review of different power quality mitigation techniques in order to enhance/improve the power quality in a microgrid in both grid connected and islanded mode. Due to increased use of non- linear loads and power electronic interface in distributed generation system, different power quality issues need to be addressed. Hence different mitigation techniques enhancing the power quality in a microgrid like FACTS devices, harmonic mitigation techniques, filters, optimization technique are discussed in this paper.

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