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A Review on Power Quality Issues and their Mitigation Techniques in Microgrid System

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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 players 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 thusfar.

KEYWORDS: *DVR; Power Quality; voltage sag; voltage swell; Microgrid; DSTATCOM; FACTS*

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1. INTRODUCTION

Microgrid is an agglomeration of distributed generation (solar energy, fuel cell, wind turbine etc.) interfaced with power electronic devices to electrical distribution network. Microgrid provides a platform to maximize reliability, availability, efficiency, security and economic performance. Microgrids can work in two modes namely grid connected mode and islanded mode. Generally microgrids are connected with main grid to avail mutual benefits between distributed generation (DG) and main network. The concept of microgrid is a viable solution for conflicts emerging by connecting large number of DGs to the grid which will result into difficulty in controlling the system and therefore may cause problem such as power quality, stability, reliability and security. Microgrid resolves the negative impact generated by DGs through optimized operation, control and proper co-ordination [1].

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 in to poor on-grid electricity pricing especially in a future power quality sensitive market[2].

M.V Manoj *e.t al* [3] 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 [4] 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 [5] 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.

This paper has been organized into six sections. Section II highlights the role of controllers in power quality improvement. Section III confers the part of FACTS devices in the enhancement of power quality in a microgrid. Different harmonic mitigation techniques are discussed in Section IV. Section V provides the contribution of optimization techniques in the enhancement of power quality. Finally, conclusion is made in section VI.

2. ROLE OF CONTROLLERS IN POWER QUALITYISSUES

[1] established the mathematical model of PV system and designed a voltage tracking controller based on Hœ control theory. The flexible Hœ 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 is utilized for the compensation of unbalance in voltage. In [7], 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. [8] 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. [9] 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.

I. 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.

1. When DSTATCOM is placed near source regulating performance isworse.
2. When DSTATCOM is placed at the end of transmission line regulating performance isbest.

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 iUPQC. 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 multicell (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.

3. HARMONIC MITIGATIONTECHNIQUES

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

1. passive techniques
2. multi-pulse rectifier techniques
3. 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 [18]. [19] 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.

4. APPLICABILITY OF OPTIMIZATION TECHNIQUESTO MITIGATE POWER QUALITYISSUES

To solve optimization problems, many techniques many techniques have emerged to solve linear and non linear problems. Particle swarm optimization (PSO) and genetic algorithm (GA) are computational intelligence based techniques used to solve problems. To address voltage harmonic elimination a different strategy is proposed in [25]. The authors selected a method which is a combination of sine PWM inverter and PSO based PWM inverter, first they eliminated higher order harmonics and then lower order harmonics by applying selective harmonic elimination (SHE) technique. The author also compared heir scheme with individual PSO and SPWM technique. The results obtained were validated with Matlab/simulink and DSP TMS320F2407A of Texas Instruments.

In order to address the power quality issues such as frequency regulation, dynamic response, voltage regulation, power sharing and THD analysis, the author Al-Saedi *et al.* [26,27,28] proposed an applicability of PSO technique to enhance power quality in an microgrid. Reference [26] is seem to be the first approach of the author to discuss the usage of PSO in the area of enhancement of Power quality in microgrid, power controller based on active power-reactive power (PQ) control during load changes and voltage-frequency(Vf)control to maintain voltage and frequency within regulating limits are utilized. In [27], for sharing the required load power between the grid and the microgrid the effectiveness of PSO Technique is successfully analyzed. The proposed controller is analyzed in two modes of operation;

1. Load demand is more than generated power
2. Power generation is more than load demand

In mode I difference power is compensated by the utility and in mode II additional power will be supplied to the main grid.

In [28] the author extended the research by utilizing the same optimizing process as in [26] to evaluate the dynamic response, harmonic distortion, steady state response in addition to regulating voltage and frequency. In this paper the proposed controller strategy consists of two control loops, one inner loop with simple PI regulator and an outer Vf(voltage-frequency) power control loop with PSO algorithm incorporated to implement a real time self tuning for the regulation of microgrid voltage and frequency.

5. 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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