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A Review on Harmonic Reduction Techniques in Three Phase Power Generation in PV Solar Plants

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Abstract: Due to higher demands of electricity, power generations with low cost are most essential needs of the world. Photovoltaic based power plant implementations are cost effective for long term power generations due to technological advancements. The harmonic reduction is most important need while establishing grid connected PV solar power plants. This paper introduces the review of various techniques for removing harmonics in PV solar power plant. The addressed techniques are studied based on their robustness, implementation complexities and performance characteristics.
Keywords: Photovoltaic solar power plant, harmonic reduction, passive harmonic filters, active harmonic filters, hybrid harmonic filters.

I. INTRODUCTION

Nowadays installations of utility scale solar photovoltaic power plants along with distributed power generation applications are rapidly growing. Effective cost reductions in solar photovoltaic cells and technological advancements and opportunistic market demands are the main factors in increment in demand. Solar power inverters are main components of the generation plants for conversion of solar power to feed to existing grid system. The semiconductor components now a days provide reliable life span for operational period thereby increasing overall system reliability and operational time along with silent operation and low environmental impact as added benefits.

In solar power plant, line frequency transformer is used to isolate the PV panels from the grid. Use of transformer is provides facilitations for reduction in electromagnetic interference (EMI) noise along with steps up or step down voltage levels. Transformer installation leads to increment in weight due to line frequency requirements and along with these additional switching circuits will be required for conversion stages which reduces overall system efficiency along with increment in costs. To avoid cost increasing factors, efficiency factors, transformers are avoided by using transformed less inverters. In photovoltaic power generation systems when no transformer is used, common mode voltage appears between PV panels and ground which leads to additional leakage currents in inverter circuits. This increments in current leads to electromagnetic interference, harmonics and losses in the system [1], [2], [3].

Variety of techniques are invented for harmonic reduction in transformer less inverter circuits. Few of them are addressed in this paper.

II. HARMONIC REDUCTION TECHNIQUES

A. Passive Harmonic Reduction Techniques

In electrical network many passive harmonic reduction techniques are available. These include tuned harmonic filters, connection of series line reactors, and pulse number conversion circuits. In these systems harmonic currents can be prevented by installing high impedance in series and diverting harmonic currents to low impedance paths explained by authors in [4]. The harmonic effects can be controlled using variety of techniques listed further.

1) Series line reactors: J. C. Das et.al. (2002) [5] have given details of this filter. Source impedance is increased in this technique with respect to load to avoid harmonics. Effect of reduction of harmonics depends on load. The overall reduction is achieved by reducing the currents.[5]
2) Tuned harmonic filters: D. Alexa et.al. (2004) [6] have shown this filter. These filters are consist of combination of series and parallel LC filters to develop high impedance and low impedance paths. High impedance is obtained for harmonic currents and low impedance is obtained for harmonic currents thereby allowing these currents to pass through only low impedance paths which ultimately separate them from line. [6]
3) Series inductor filters: T. S. Key et al (1993), A. R. Prasad et al (1990), J. Yanchao et al (1998) have given details of this filter. Inductors are known to have better filtration characteristics. The induction value is chosen such that only harmonics are blocked

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and remaining are allowed to pass. These filters are specifically applicable to AC-DC conversion circuits. These filters can be used on either side i.e. AC or DC. [7-9]

4) DC-DC conversion with shaping circuits: K. Hirachi et al (1995) [10], have shown this type of filter. In DC-DC conversion process, combination of inductors and capacitors are used to shape the particular harmonics thereby creating absence in line currents.[10]
5) Parallel resonant filters: As shown by D. Alexa et.al. (2004) [6], these filters developed by using LC parallel combinations are used to resonate at exact harmonic frequencies which thereby reduce the effect of presence of harmonics. These filters are connected in parallel to the load and work as a function of load.[6]
6) Series resonant filters: As shown by D. Alexa et.al. (2004) [6], these filters developed by using LC parallel combinations are used to resonate at exact harmonic frequencies which thereby reduce the effect of presence of harmonics. These filters are connected in series with the load and work as a function of load.[6]

B. Active Harmonic Reduction Techniques

These filters are developed using active devices such as IGBTs instead of inductor and capacitors.

1) Series active filters: As shown by H. Fujita et.al. (1991) [11], In these filters filter transformer is connected in series with load. The transformer output is controlled via switching of IGBTs controlled by microcontroller based platforms. The microcontroller is given with feedbacks to analysis and further control the harmonics by changing the switching. The block diagram of shown in figure 1 shows the typical series active filter arrangements. [11]
2) Parallel active filters: As shown by H. Fujita et.al. (1991) [11], in these filters filter transformer is connected in series with load. The transformer output is controlled via switching of IGBTs controlled by microcontroller based platforms. The microcontroller is given with feedbacks to analysis and further control the harmonics by changing the switching. The block diagram of shown in figure 2 shows the typical parallel active filter arrangements.[11]

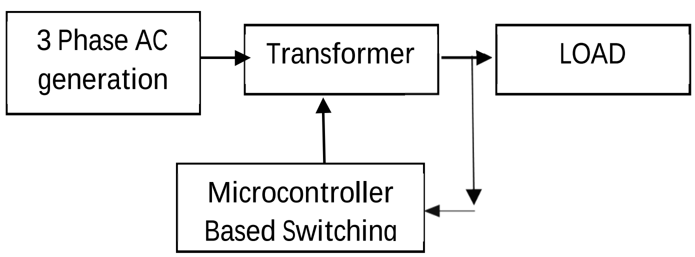

Figure 1: Series Active Filter

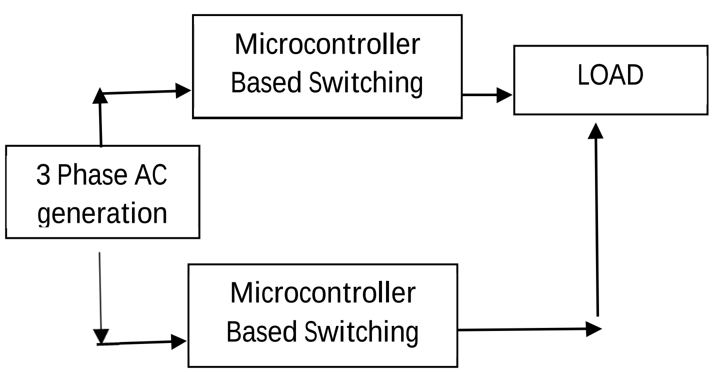

Figure 2: Parallel Active Filter

C. Hybrid Harmonic Reduction Techniques

Connecting together active harmonic filters and passive harmonic filters form hybrid harmonic filter. In passive harmonic filters fixed compensation characteristics limit the performance. In active harmonic filters though performance is optimum, cost of construction is too high. To solve these problems effectively hybrid harmonic filters topologies are developed [12-19].

1) p-q Method: B. R. Lin et.al. (2002) [13] have shown the method, in which depend on instantaneous reactive power. The reactive power depend not only on load characteristics but also generation system. If three phase system is unbalanced, this method performance decreases.[13]
2) d-q Method: The method indicated by D. Chen et. al. (2004) [14], three phase current component is decomposed into positive sequence and negative sequence using phase locked loop circuits. The phase gets locked at specific point where lowest harmonics are seen. This is achieved through counter transformation.[14]
3) Direct Testing and Calculating Method: This method can be studied from [15] given by K. Zhou et al (2010). Direct harmonic component compensating is done in this method. This system works by reference frame transformation. The drawback of system is DC bus offset voltage.[15]
4) Synchronous Reference Fame Method: The method indicated by D. Detjen et. al. (2001) [16], Current components are transformed into reference frame to synchronize with mains voltage and current frequency. The advantage is that, three phase generator imbalance does not affect the synchronization and hence harmonic reduction performance. [16]
5) Current hysteresis control: The method given by M. Aredes et al (1997) [17] the hysteresis current is controlled by changing switching frequency with reference to error signal derived from reference signals. This system is robust in nature but requires additional circuits to generate error signal and steady state reference signals which increases complexity and cost of implementation.[17]
6) PWM Control: In [18] method given by M. Aredes et al (2003), the switching is controlled by derived signal characteristics by direct harmonic measurement system. The PWM is responsible to control the current and voltage with reference to generator and load characteristics thereby increasing overall system performance and keeping implementation costs at low.[18]

III. CONCLUSION

In this paper we have studied various techniques of harmonic reduction developed by various researchers. The techniques are studied on the basis of implementation feasibility, operations methods, and performance in harmonic reduction. By studying these techniques we can conclude that, the passive techniques are responsible to reduce harmonics efficiently but overall losses on overcoming harmonics reduce system efficiency. Active harmonic filters are capable of reducing harmonics without affecting system efficiency but implementation cost is so high. Hybrid systems which are combination of passive and active harmonic filtering systems are reliable and robust in terms of performance and implementation cost and complexity also low.

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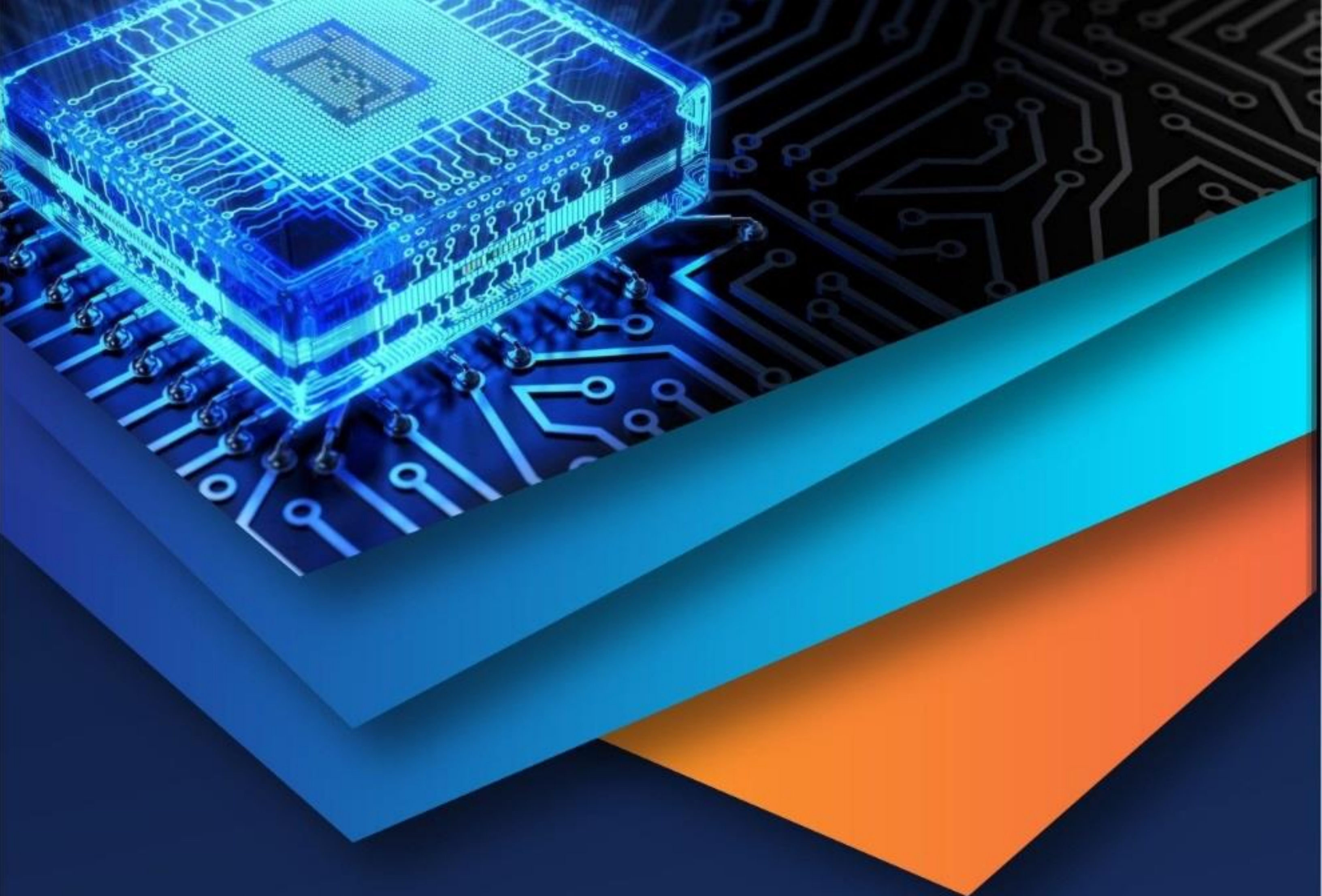

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