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A Review on Control Strategies of Grid Connected Solar PV Generating system

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Abstract— **Solar energy in directly converted electrical form such as solar PV energy system has gained momentum in the recent years worldwide. With the rapid development of solar cell fabrication technology, the reliability and cost has come down so as to be competitive with the other renewable energy source counterparts. Moreover large scale production of this eco-friendly and green energy source motivated the energy utility authority to go with policy making to tap solar power in grid connected solar power generating mode. That is why researchers and scientists took greater initiatives in the area of developing various control strategies to solve different problems arising out of feeding solar energy to the utility grid. As modern power grid is very complex in terms of controllability and maintaining stability, there is challenges for the control engineers to develop the most reliable and efficient control strategies for such grid connected systems. Hence a review study has been presented in this paper to highlight the focus area in grid connected PV system such as mitigation of harmonics, grid code compliance and control aspects of such system.**

Index Terms— **grid-connected, solar PV,Maximum Power Point Tracking, controllability**

I. INTRODUCTION

Due to suitability in distributed generatation, satellite system and transportation, PV system is considered to be the most promising technology [1]. In [2] it is shown that there are two modes viz. (i) Grid connected mode and (ii) Island mode (Stand Alone mode)

In grid connected mode maximum power need to be delivered into the grid by adopting various MPPT algorithm such as Perturb and Observe method, Incremental Conductance method, Controlled Voltage Technique etc. For this there is necessity of a set-up transformer which reduces efficiency of the system and increases cost of PV array with high DC voltage. High voltage system represent hot spot during partial shadowing as well as leakage current between the panel and system ground through parasitic capacitance.

VSI is most commonly used for grid connected PV system for its simplicity [3].But it needs a bulky transformer and high level of DC link voltage. To overcome these problems such as improved ac side wave form quality, reduce electrical stress on power switches and reduce power loss due to high switching frequency, several multilevel inverter topologies have been proposed.[4-7] CSI produces high dc current as well as even harmonic on DC side and odd harmonic on AC side [8] .Therefore an inductor with large value and bulky in size are used which is practically not acceptably. For that two salutations are proposed in different literature

(i) Feedback current control
(ii) Hardware technique.

Feedback current control eliminates odd harmonic without bulky inductor [9] and in [11] Hardware salutation is used to mitigate even harmonic from the DC link by using parallel resonant circuit which affect cost ,losses and size of the system .By modification of carrier signal on PAM, which is varied with second order harmonic component from dc link current mitigated power oscillation [11]. In [10] it also emphasizes the use of NPWM for elimination of second order harmonic. The drawback of this technique is that the oscillation of dc current is very large which results in high loss and reduce the life span of the system. The common mode current can flow in the resonant loop without galvanic isolation [7-9].This results in

II. TOPOLOGICAL FEATURES

The topology for off grid operational mode inverter is divided into two group

(i) half bridge inverter and (ii) full bridge. Inverter

In half bridge configuration, neutral conductor is connected to the mid point of the supply voltage. As a result of fixed voltage across the parasitic capacitor, the value of common mode voltage is set to zero [15].In full bridge converter the common mode current can be controlled by imposing common mode voltage which implies zero common mode current by PWM. A sinusoidal voltage of half of the voltage magnitude is impressed across the parasitic capacitor [16]. The drawback of this topology is that a sinusoidal common mode voltage is present regardless of modulation.

III. CONTROL STRATEGIES

The low voltage ride through capacity and control of front end power converters are the most complex technical issues [17-20] .The unbalance grid voltage condition is due to voltage sag which gives rise to uncontrolled oscillation in the active and reactive power of grid. This effect can be mitigated by injecting a proper set of unbalance current. Here the control reference have been generated. The current controller must provide full capability for injecting the positive

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sequence and negative sequence component currents that compensate the desired unbalance currents. Resonant current controller [17,21] , direct power control method [22,23], model based predictive control [24,25] can be used for controlling the operation of grid connected power converter under abnormal grid condition. In [25] the direct relationship between the active and reactive power with dq current component is analysed which determine the current reference for injecting a certain active and reactive power to the grid.

The interaction between current vector and reference frame with different sequence gives rise to oscillation in dq signal obtained from Perk's transformation [29]. This oscillation has been controlled by PI controller. [26, 27, 28]

PV panel should be grounded through a parasitic capacitance. Because due to switching action inverter injects a capacitive ground current [30].This ground capacitance is a part of resonant circuit which consists of PV panel , AC filter and grid impedance [31].Depending upon switching action this ground current cause Electromagnetic Interference, grid current distortion and losses in the system [32,33].

A new topology is discussed in the substitution of full bridge inverter for neutral point clamp(NPL) [34] .In Germany every PV system is connected with a residual current monitoring unit RCMU, which absorbs ground current, if it is greater than 300 ma and the system is disconnected in 0.3 sec. Ground current is super imposed to line current .Therefore harmonic content increases and the loss increases.

For harmonic compensation additive filter is used [35-39]. In [35] additive filters are used to estimate harmonics. These harmonics are added to main current reference. A multi resonant block is used to ensure zero steady state error for a particular harmonic. So overall complexity increases. Similarly in [36,37] it takes harmonic current as reference and uses additive filter and hysteresis controller for the reference tracking. The hysteresis controller is very fast but is having a varying switching frequency. In [39] additive filter based method for dead time compensation in rotating frame has been presented. An inverse transfer function is used in [40].

In [41] a particular harmonic in the grid current is estimated using a LMS filter and corresponding harmonic voltage reference is generated using a proportional controller. This voltage reference is added with appropriate polarity to the fundamental voltage reference to attenuate that particular harmonic. Due to presence of DC in the inverter terminal voltage, DC current flows into transformer primarily. As a result it draw even harmonic currents from grid. It uses PR controller, which represent any dc offset in control loop that propagates in the system. The inverter terminal voltage will have a non-zero average value.

The model of PV generation system [42] can be used for studying its interaction with power system. The MPPT part of the control system of PV generator predicts the dynamic behavior of the system. This model gives the characteristics of the generator in response to small and fast changes in irradiance and ac grid voltage. The MPPT tracking system set the inverter voltage reference signal which adjust the dc voltage V_{PV} at the output of the solar array. The Perturb and Observe(P & O) technique has been used due to its simplicity and accuracy through variation in irradiance and temperature.

A MATLAB/SIMULINK model of a single phase grid connected PV inverter has been developed and experimentally validated for its performance characteristics [43]. In this work the PV model developed has been integrated with full gradient based MPPT model.

The control algorithm proposed in [44] for single stage grid connected PV system comprises of an inner current control loop and an outer dc link voltage control loop. The current control strategy protects the PV system from external fault, enables dc link voltage control. Thus PV system output power can be controlled optimally. A feed forward compensation strategy for the dc link voltage control loop to overcome the effect of non linearity of the PV array characteristics on the closed loop stability has also been implemented. This enables the dc link voltage controller to operate optimally for a wide range of operating conditions

A robust maximum power capturing controller to generate MPP reference voltage under rapidly changing irradiation has been proposed in [45].The MPPT algorithm is implemented without the measurement of the PV array power. The change in power due to simultaneous increment perturbation and irradiation variation are decoupled. Signal error of a PI controller of the dc voltage control estimate the irradiation variation. The d-axis grid current component reflects the grid side power change.

The operation of transformerless PV inverters having Low Voltage Ride Through (LVRT) capability under grid faults have been proposed in [46]. The control strategies with reactive power injection has been presented. The performance of three inverter topologies viz. i. Full bridge inverter with bipolar modulation ii. Full bridge inverter with DC bypass and iii. Highly Efficient and Reliable Inverter Concept(HERIC) has been analysed. It has been experimentally concluded that HERIC, though superior to other two topology in terms of efficiency, it is not effective in case of voltage sag. On the contrary, the other two topologies have the capability of reactive current injection during LVRT.

In [47] a novel MPPT algorithm using the open circuit voltage and the short circuit current of a reference PV panel is proposed. A buck boost converter has been used for impedance matching between source and load to achieve maximum power transfer. The MPPT varies the electrical operating point of the PV module thereby allowing maximum power transfer.

IV. CONCLUSION

In view of the popularity and technological development of solar energy system extensive research and review has been intensified over the last two decades. Still many advanced deliberations and thoughts need to be put in this emerging area to give better and sustained option in the area of renewable energy generation system. Hence there is a need for the through review and exploration of the research outcome in the area of solar energy system. Still more important is the review study on the solar PV generating system operating in the grid connected mode as more and more power are being injected to the existing power grid. Grid code compliance is a mandatory requirement to be fulfilled by the generating companies to ensure a more vibrant and enhanced power quality in view of greater penetration of solar energy. A detail study on various topology and control aspects of solar PV generating system in the grid connected mode has been discussed in this paper.

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