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Design and Implementation of Grid Connected Solar Inverter using Adaptive Harmonic Elimination Technique

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Abstract: Our project mainly focuses work a lot being carried out in the field of distributed generation. For the electric grid, so Many distributed generation systems are being made. At this time when the non-renewable sources of energy such as oil, coal, etc are very fast disappearing, a study of distributed generation systems (DGs) and Establishing of such systems using renewable sources of energy becomes very important. we have seen several major problems will happen, when harmonic content of the current is flows into the grid, like this issue several issues are going to meet. When a Distribution Generation source is being linked to the grid. "The current being injected should have harmonic content conforming to standards such as IEEE 512-1992"[1].To limit the harmonic current injected into the grid. The hardware is tailor-made to be used for a solar PV panels based distributed generation system. This project deals mainly with Establishing the hardware for a grid connected inverter. This means that a proper plan of action should be present in the required system, special type of filters are made to abolish higher order harmonics, this is only the reason why filters would be less bulky and cheap. only the higher order harmonics are decreased by specially made filters, Lower order harmonics are attenuated by a technique called "an adaptive harmonic elimination technique (AHE). In our project we need to develop several blocks called the inverter hardware, design and implementation of closed loop control, transformer, the filters along with adaptive selective harmonic elimination scheme

I. INTRODUCTION

Solar, wind, geothermal etc the Non-conventional energy sources are playing vital role because coal gas etc conventional energy sources decreasing day-by-day. These renewable energy sources are becoming very important in electric power generation. Presently the renewable energy sources are being designed and connected to grid With many distributed generation systems. Fig.1 shows a schematic diagram of a distributed generation system (DGS) with solar energy as the source. As in Fig.1, power converters, filters, transformers are required as the hang-together connecting the energy source and the grid. The proper functioning of the DG systems depends very much on the design of the interface.

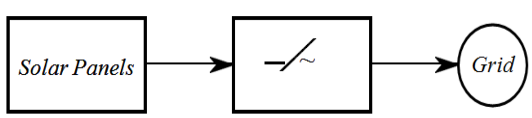

Figure.1: Distributed Generation System

The design of the interface, usually consisting of the power converter, filter and transformer is looking forward to meet the following criteria: The grid was given by amount of harmonic current which specify the standards "the standards IEEE519-1992[19]". And interconnection of Distribution Generation Systems with the electric power system which is a standard for "IEEE1547-2003[20]". Which is a standard for interconnection of DGS with the electric power system. Reliability and Cost Reduction. This project –deals with the complete design and control of Solar panels are used as the source, when a power converter suitable for a 'distribution generation systems'. Fig.2 shows the power circuit topology.

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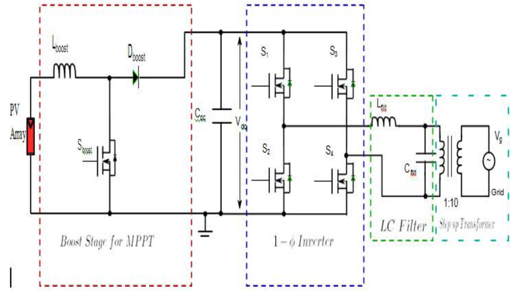

Figure.2: Power circuit topology

At maximum power point tracking MPPT, a boost-stage is required to operate solar panels, where solar panels are considered as source(From measurements). the panels give maximum power, Only at a particular operating point. The boost stage is used to adjust the resistance seen by the panels by controlling its duty ratio, hence keeping the panels at MPPT. This arrangement is essential to have a better efficiency of the entire system. the 1- Ø H-bridge inverter is follows the boost-stag .The switches of the inverter are modulate during sine-triangle PWM to convert the dc input in to pulsating ac voltage output. The solar panels voltage levels are quite small because inverter switches are MOSFETs. V_{mpp} is around10-12V. The filter is connected output of the inverter (either *L* or *LC*). Ideally, switches of Pulse Width Modulation shift all the harmonics to switching frequency & its multiples. Lower-order harmonics are present in real systems, higher order harmonics are decreased by specially designed filters. The following factors are answerable for the existence of lower order harmonics: The dead-time inserted between the switching's of devices of the same leg[5] The on-state voltage drops on the switches The transformer draws the magnetizing current is usually rich in lower order harmonics, In order to decrease the amount of lower order harmonic current into the grid, The filter size increased by a simple solution. But this makes the filter bulky and increases the cost. a special technique is called 'an adaptive harmonic elimination technique (AHE)[1]' is used to limit the injection of these harmonics into the grid. A part from the hard ware development, the project work involves the closed loop control of the power converter. The current source is controlled by a power converter. As the inverter is single phase, a PR controller is used in the current loop to have zero steady state error.

II. SIMULATION RESULTS

In this paper, simulation results of the current-control are presented. The results prove the validity of adaptive harmonic elimination (AHE) technique in the attenuation of lower order harmonics.The transformer magnetizing current make distortions which are not considered in the simulations. Transformer magnetizing current reduced by an effective technique, this is shown in experimental results.

Parameters used for simulation The simulation results shown in this chapter are the following four cases Current control at low load without AHE Current control at low load with AHE Current control at higher load without AHE Current control at higher load with AHE The AHE blocks are used for 3rd, 5th, 7thand 9thharmonics. Current controller parameters used are the same as For the adaptive control the proportional gain constant used is 10. Dead-time used is 1.5µSLow load without AHE The current reference given is 1.6A. The output current and its low frequency spectrum are shown inFig.3.

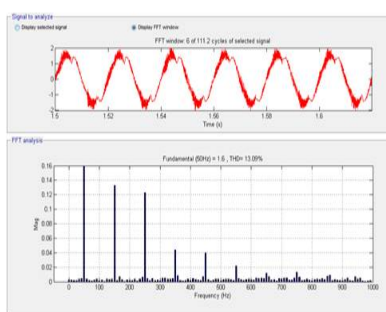

Figure 3: Output current and its spectrum without adaptive compensation (low load)

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Low load with AHE For the same current reference as in section 4, adaptive compensation is included. The result is shown in Fig.4.

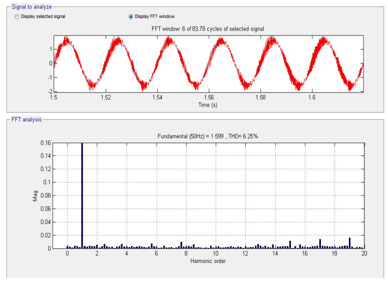

Figure 4: Output current and its spectrum with adaptive compensation (low load)

Higher load without AHE The simulation is carried out for a current reference of 6.4*A* which is close to the full load case. Fig.5. shows the result without compensation

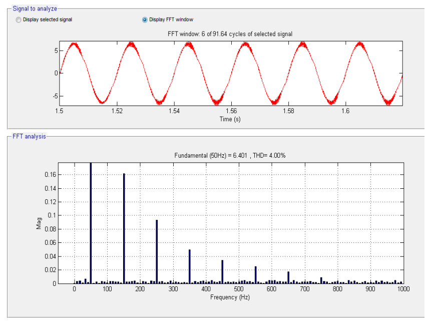

Figure 5: Output current and its spectrum without adaptive compensation (high load)

Higher load with AHE For the same current reference as in section 6, adaptive compensation is included. The result is shown in Fig.6.
The simulation results clearly indicate that the adaptive compensation is quite effective.

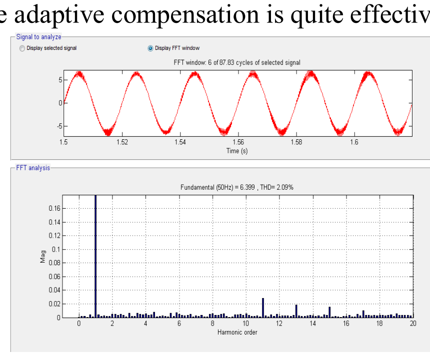

Figure 6: Output current and its spectrum with adaptive compensation (high load)

III. EXPERIMENTAL VALIDATION

Initially, some difficulties were observed in the grid connected case to run the system. The following points explain the associated problems and how they were solved. The inverter is given grid voltage feed-forward as reference, means the system is configured. So there would be some current injection into the grid initially. By pressing push button on the FPGA control board, the closed loop control system is initiated. The push button on-board was established to lack a hardware de-bounce logic. The controller would not settle and system would trip with the help of the push button on-board. The problem was rectified by making a FSM which takes the input from push-button and gives a clean control enable signal. The gate driver ICIR2110 can drive the high side switch of a leg only after the bootstrap capacitor gets charged. To charge the bootstrap capacitor, the bottom switch has to turn on. So when the control is enabled, the top switch of one leg and the bottom of the other have to be kept ON to start injecting current. This will not happen unless the bootstrap capacitor holds sufficient charge. As that would not happen, the grid the efficiency of the overall system was checked for operation in both stand-alone and grid connected case.

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The measured overall efficiency was in the range of 82-84% in all the cases. This is lesser than the predicted efficiency of around 87%. There was no significant variation in efficiency for the cases with and without compensation.

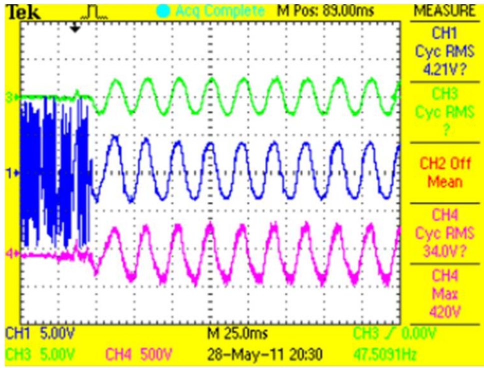

Figure 7: Load voltage [CH4: Pink; Scale: 1V/1V] , voltage reference [CH1: Blue; Scale: 1V/1V] and secondary current [CH3: Green; Scale: 1A/1V] stand-alone with transformer and with secondary side compensation

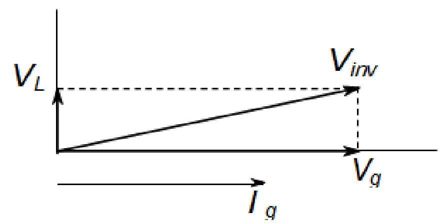

Figure 7: Phasor diagram for upf operation

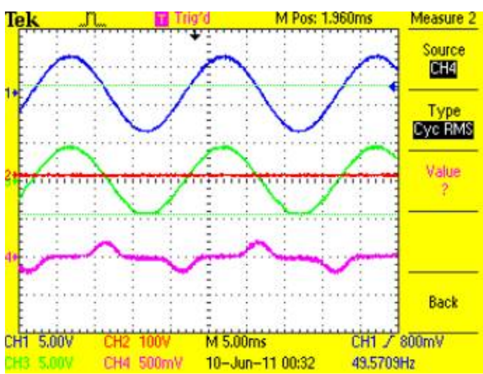

Figure 8: Sensed grid voltage [CH3: Green; Scale:1V/1V] , in phase unit vector [CH1: Blue; Scale:1V/1V] , secondary current [CH4: Pink; Scale: 1A/1V], primary current [CH2: Red; Scale: 3.2A/1V] when inverter is OFF

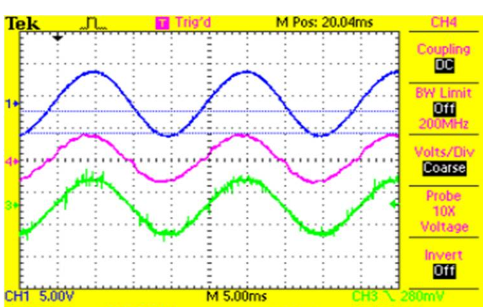

Figure 9: Sensed grid voltage [CH3: Green; Scale:1V/1V] , in phase unit vector [CH1: Blue; Scale:1V/1V] , primary current [CH4: Pink; Scale: 1A/1V] for upf operation

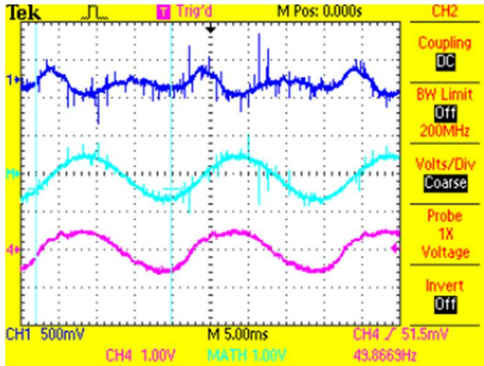

Figure 10: Fundamental component of secondary current [MATH: Cyan; Scale:1A/1V], Net harmonic current[CH1: Blue; Scale:1A/1V , secondary current [CH4: Pink; Scale: 1A/1V] for upf operation

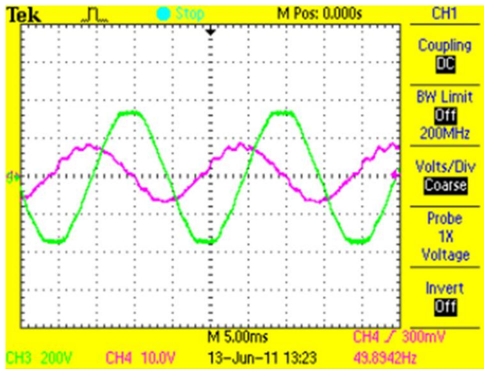

Figure 11: Grid voltage [CH3: Green; Scale:1V/1V], primary current [CH4: Pink; Scale: 1A/1V] for 0pf lead operation

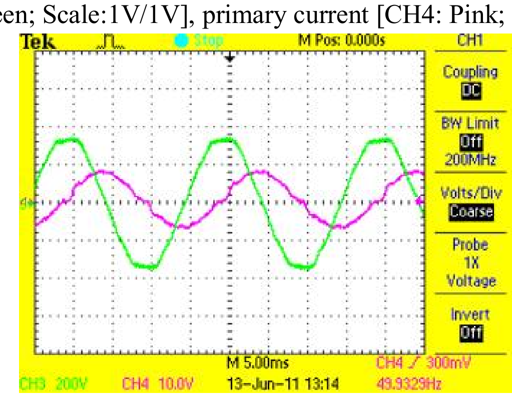

Figure 12: Grid voltage [CH3: Green; Scale:1V/1V], primary current [CH4: Pink; Scale: 1A/1V] for 0pf lag operation

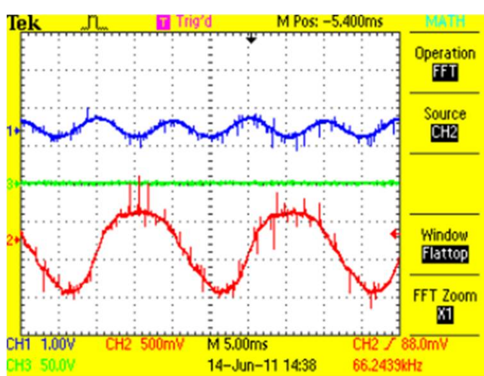

Figure 13: Grid current [CH2: Red; Scale: 1A/1V], Second harmonic component of grid current [CH1: Blue; Scale: 1A/1V] for upf operation

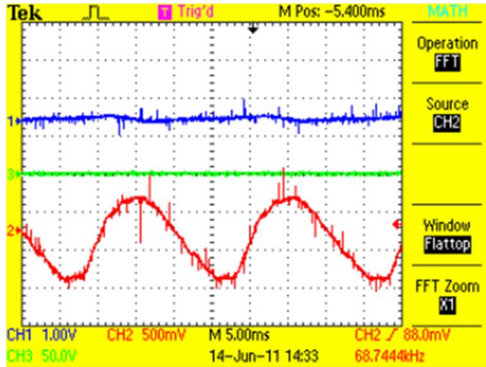

Figure 14: Grid current [CH2: Red; Scale: 1A/1V], Second harmonic component of grid current [CH1: Blue; Scale: 1A/1V] for upf operation with adaptive compensation.

IV. CONCLUSIONS

The project was aimed at developing the hardware and control scheme for a low power grid connected inverter. The motivation for this was to have a compact, efficient and economical hardware for the PV panels present in Simi-link file. The issue of presence of lower order harmonics in real systems was intended to be addressed using an adaptive harmonic elimination technique (AHE). Literature survey revealed that the effectiveness of AHE scheme was not tested in hard- ware. Hence the aim of the project was also to validate the effectiveness of this technique in hardware. The hardware built for the project consists of: A main circuit board consisting of power circuit, and control circuits such as protection- delay circuit, indicator circuit, gate-drive circuit and on-board control power supply. A general purpose non-isolated voltage and current sensor board consisting of five voltage channels and four current channels. The magnetic components-inductors and transformer the control developed for the hardware consists of the closed loop current control with AHE. As the system is meant to be operated in grid interactive mode, a single-phase PLL was designed. All the control was implemented successfully in FPGA controller coded using VHDL. Certain issues like frequent tripping of the system were observed in grid interactive mode initially. The issues were solved by solving the de-bounce problem, gate-driver problem of the hardware which were the major reasons for the trips. The adaptive harmonic technique was found to be quite effective in hardware for compensating the dead-time effect and distortion due to transformer magnetizing current. It was also seen in grid connected operation, that the ripple on dc bus voltage introduces significant even harmonics in the system. The adaptive technique was attempted to compensate for this effect also. The technique did improve the wave shape, however, its effectiveness remains to be verified against some other techniques available to compensate for dc voltage ripple. This is because adaptive technique might not be suitable for attenuating distortions due to dc bus ripple. The distortions due to dc bus voltage ripple are decreased by adaptive harmonic technique if injection of dc current will happen. The hardware was tested with dc source as PV emulator. The system performance is to be verified with the actual PV panels as the source.

The system is expected to function properly with the PV panels as the source also, as the panels are essentially dc sources. The MPPT, however, is required to be implemented while using PV panels, to improve the efficiency and to utilize the available solar power better. Overall, the aim of building the hardware with closed loop control was successful. System efficiency was acceptable but could be improved further by more judicious design of trans- former and selection of switches with less on-state drops. The compensation method studied and implemented was AHE. Other methods of harmonic elimination such as multi-resonant controllers [14], hardware dead-time compensation technique [5] etc can also be investigated. In this work, the transformer is in the grid side. The other configuration that can be considered is with a high frequency link transformer. Also, the EMI issues with the hardware are to be studied and compliance to EMI standards is to be ensured.

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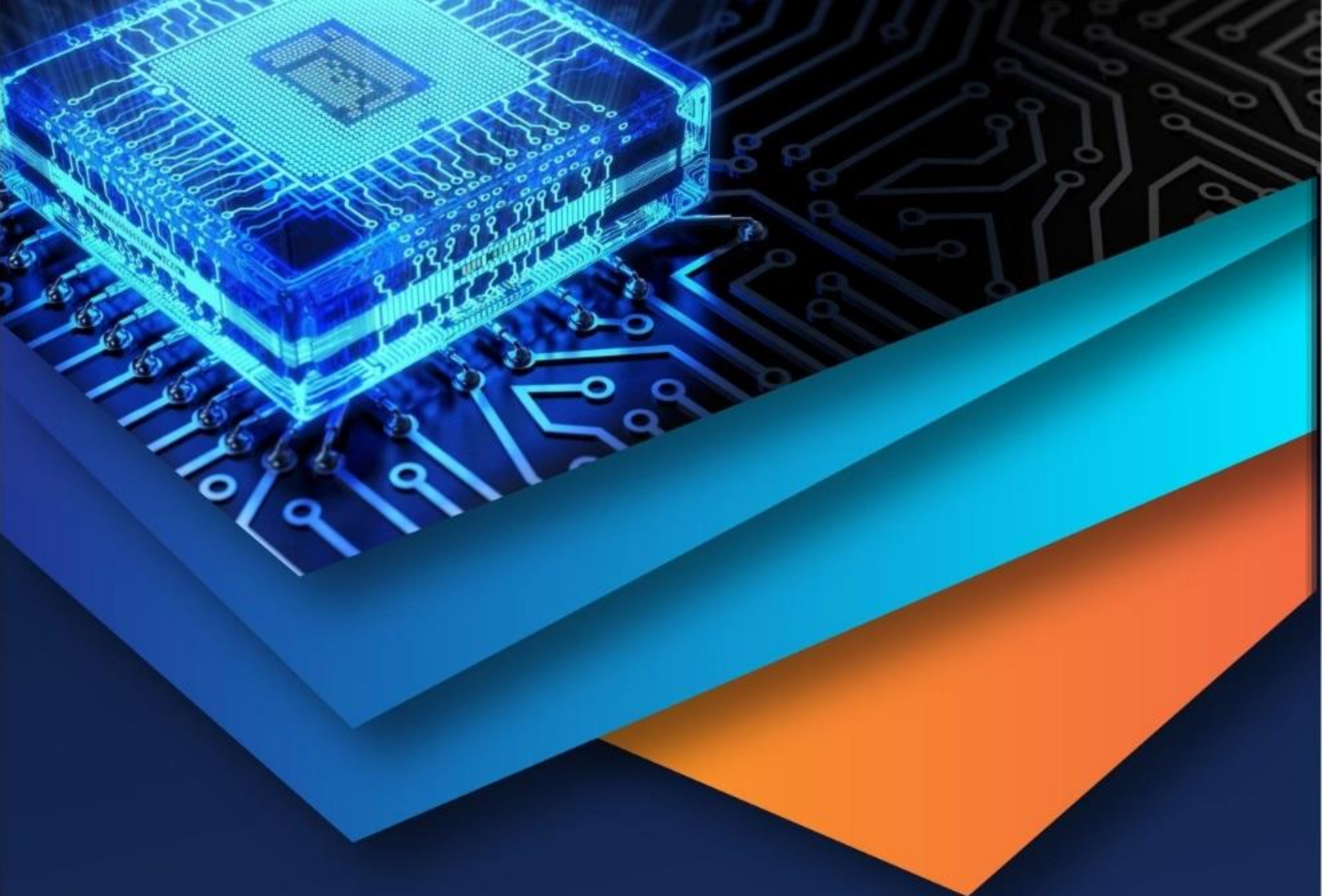

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