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POWER ELECTRONIC BASED DISTRIBUTED GENERATION UNITS FOR HARMONIC COMPENSATION WITH FUZZY LOGIC CONTROLLER

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Abstract- **Power electronic converters have rapidly emerged as one of the main used devices to interchange energy with the utility grid, at several power and voltage levels. In this context, VSC based converters are among the most preferred interfaces to perform the interconnection, especially for integration of distributed energy sources, active filtering, and power supply applications due to the control strategies development. In Electrical Power Distribution System (EPDS), non-linear loads are the main cause of power quality (PQ) degradation. The level of distortion depends on the internal elements of the DGUs. This project presents a comprehensive method, focused on power-quality indexes and efficiency for the design of microgrids with multiple DGUs interconnected to the ac grid through three-phase multi-Megawatt medium voltage pulse width-modulated-voltage-source inverters (PWM-VSI).**

In the future extension, we use fuzzy logic controller design results of the presented case studies have shown a remarkable performance, offering an excellent power quality with the best efficiency possible in the presence of low switching frequencies. Matlab/simulink simulations are presented in order to show the outstanding performance of the proposed design approach.

Proposed system: PI controller

Extension system: fuzzy logic controller

I. INTRODUCTION

The electric power system consists of three major functional blocks:-generation, transmission and distribution. As per reliability consideration in power system, generation unit must generate adequate amount of power, transmission unit should supply maximum power over long distances without overloading and distribution system must deliver electric power to each consumer's premises form bulk power systems. Distribution system is located at the end of electric power system and is directly to the consumer, so the power quality depends upon the state of distribution system. The reason for this is that failure in the electric distribution network accounts for about 91% of the average consumer's interruptions. Earlier, power system reliability focussed on generation and transmission system due to capital investment in these.

But today, distribution system is receiving more attention as reliability is concerned. The main cause of terminal voltage fluctuation, transients and waveform distortions on the distribution system are the utility and customer-side disturbances. Now days, power quality engineers are progressively more worried about the quality of electrical power. In modern industries, electronic controllers are used by load equipment, as they are sensitive to poor voltage quality and if supply voltage is depressed they will shut down and may operate, if harmonic distortion of the supply voltage is excessive. Electronic switching devices used by new load equipments, can supply poor network voltage quality. Power quality issues are achieving a major concern due to the increase in number of sensitive loads. Also the extensive use of electronic equipment, such as information technology equipment, adjustable speed drives (ASD), arc furnaces, electronic fluorescent lamp ballasts and programmable logic controllers (PLC) have entirely altered the electric loads nature. These loads are the foremost sufferers of power quality problems. the nonlinearity of these loads cause disturbances in the voltage waveform. a utility will likely to deliver a low distortion balanced voltage to its customers, particularly those with sensitive loads.

The design of two DGUs, based on three-phase PWM-VSIs, which are connected to a microgrid is presented. Two case studies are presented to show the proposed design approach, one considering that the interconnections grid is unknown and the other when is known. The obtained results show the remarkable good performance of the proposed design approach on both cases, along with advantages over other design methodologies, which rely on the comprehensive consideration of multiple design objectives.

OBJECTIVE OF THESIS

This project presents a comprehensive method, focused on power-quality indexes and efficiency for the design of microgrids with multiple DGUs interconnected to the ac grid through three-phase multi-Megawatt medium-voltage pulse width-modulated-voltage-source inverters (PWM-VSI). The proposed design method is based on a least square solution using the harmonic domain modeling approach to effectively consider explicitly the harmonic characteristics of the DGUs and their direct and cross-coupling interaction with the grid, loads, and the other DGUs. Extensive simulations and analyses against matlab/simulink are presented in order to show the outstanding performance of the proposed design approach.

II. LITERATURE SURVEY

A.Medina, J. Segundo, P. Ribeiro,W. Xu, K. Lian, G. Chang, V. Dinavahi, and N.Watson[1], Harmonic analysis has been carried-out using frequency, time and hybrid time-frequency domain methods. The conceptual and analytical details of these methods are concisely detailed in this contribution. A concise overview on simulation methods for harmonic analysis has been previously reported. Their application was illustrated in a companion paper with examples and sample systems. Further advances on methods for harmonic analysis in frequency and time domain are detailed and more recently, where in addition to the above, an alternate sub-division of methods for harmonic analysis is proposed. This paper presents a concise yet detailed revision of theoretical fundamentals and principles of classical methods for harmonic analysis. A precise and simple classification of methods is given.

X. Wang, F. Blaabjerg, and W. Wu[2], the harmonic stability caused by the interactions among the wideband control of power converters and passive components in an ac power-electronics-based power system. The impedance-based analytical approach is employed and expanded to a meshed and balanced three-phase network which is dominated by multiple current- and voltage-controlled inverters with LCL- and LC-filters. A method of deriving the impedance ratios for the different inverters is proposed by means of the nodal admittance matrix. Thus, the contribution of each inverter to the harmonic stability of the power system can be readily predicted through Nyquist diagrams. Time-domain simulations and experimental tests on a three-inverter-based power system are presented. The results validate the effectiveness of the theoretical approach.

III. SYSTEM MODELING

Three main elements could be identified in the design of a DGU. (1) The Design Objectives (DO) (power quality, operating conditions, size limitations, cost, etc.), (2) the External Conditions (EC) (distributed resource, grid equivalent, weather events, faults, generation outages, etc.) and (3) the Designable Elements (DE) (topology, component values, control parameters, etc). In this context, a proper design can be summarized as the selection of certain DE that ensures the fulfillment of the DO in the presence of some EC. This requires understanding in detail the relationships and interactions among these main elements. Fig. 5.1 shows a very basic representation of a typical DGU and some of the above identified main elements are shown (DO, EC and DE). From Fig. 5.1 the DO could be established, for example: DC bus voltage, DC voltage ripple, RMS voltage at *PCC*, active power at *PCC*, reactive power at *PCC*, THD voltage at *PCC*, current ripple at *PCC*, among others. Some of the DE are: distributed resource topology, power electronic topology, AC and DC filter topologies, control unit topology, switching frequency, power switches ratings, DC filter component values and AC filter component values, control unit gains, among others. In order to have a selection of the DE that ensures that the reference design objectives (DOref) are met under bounded variation of certain EC, is then required to understand the relationships between these main elements.

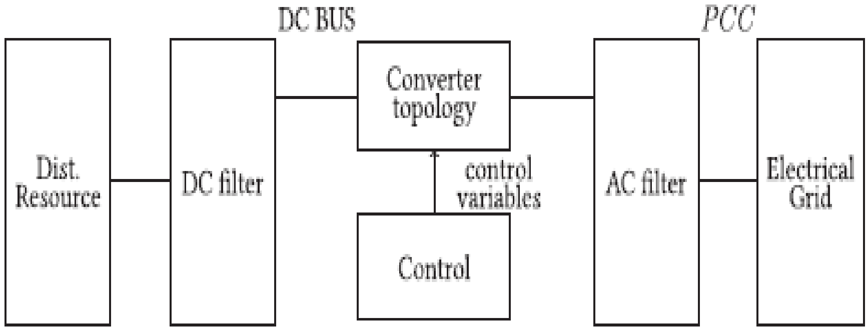


Fig.: Simplified layout for design.

III. SIMULATION RESULTS

In order to show the flexibility of the proposed design approach, two design cases studies are presented in this Section for the microgrid test system proposed in Fig.. The first case considers that no information of the microgrid test system where *DG*1 and*DG*2 will be connected is available, named as isolated design. The second case considers that the microgrid test system where *DG*1 and *DG*2 will be connected is known, named as comprehensive design. The main objective in both cases is to find the designable elements proposed in Section for *DG*1 and *DG*2 which meet as close as possible the reference design objectives of an steady state operation of the case study system.

CASE-1: MICROGRID TEST SYSTEM OF AN ISOLATED DESIGN

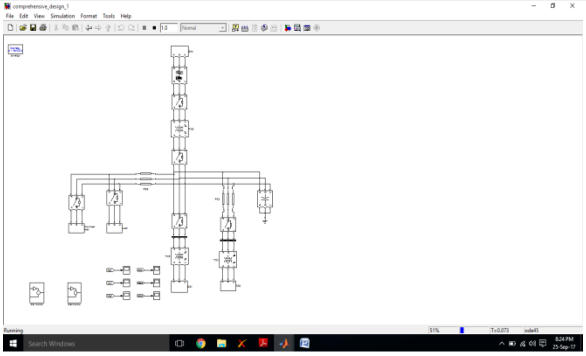
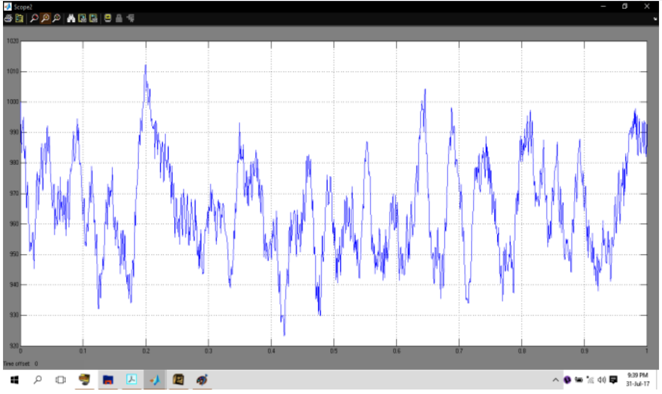
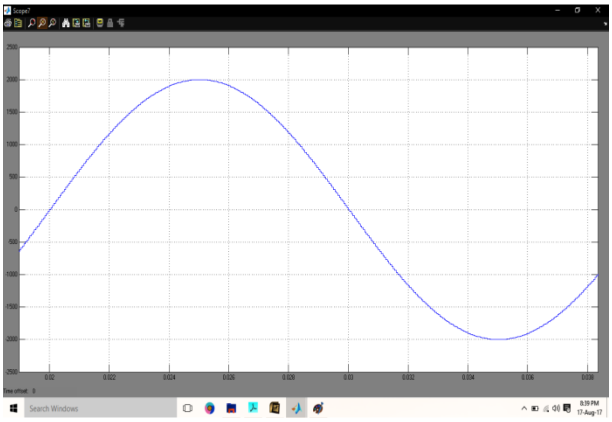


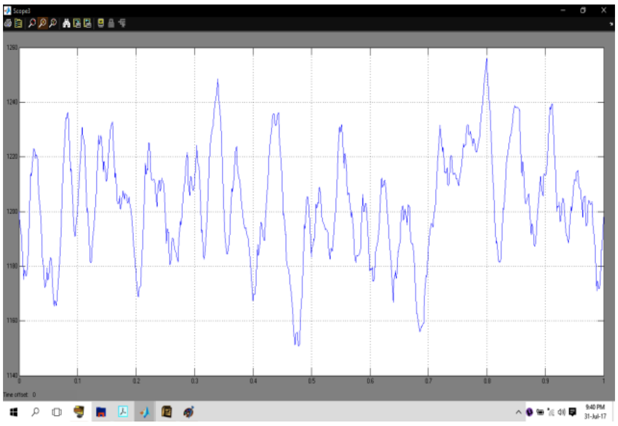
Fig:. Simulation diagram of a microgrid test system of an isolated design



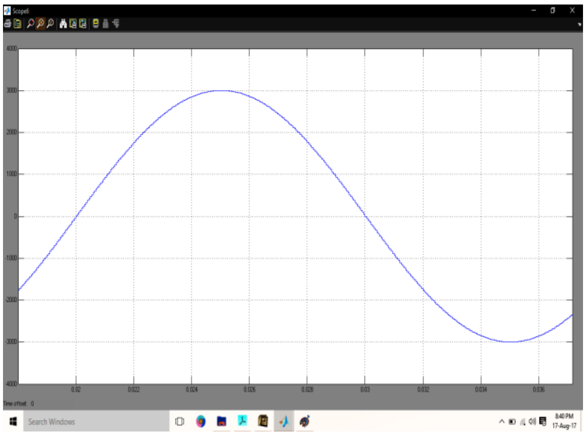
(c) *DG1 v1dc* voltage.



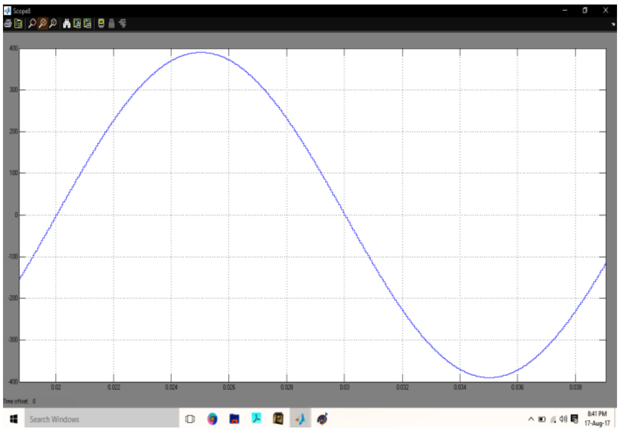
(a) DG1 i11 converter current.



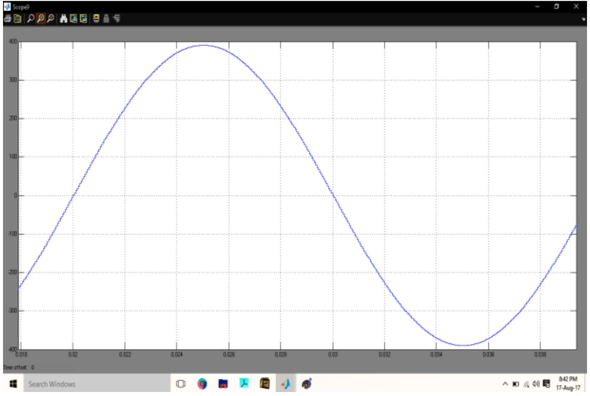
(d) DG2 v2dc voltage.



(b) DG2 i21 converter current.



(e) DG1 node 1*A* voltage.



(f) ***DG*2 node 2*A* voltage.**

The achieved power-quality indexes are excellent considering the high power capability and low switching frequency considered in the design. When interconnected to the microgrid, each DGU behaves very close to an ideal harmonic free voltage source and their overall harmonic distortion impact over the microgrid is practically negligible.

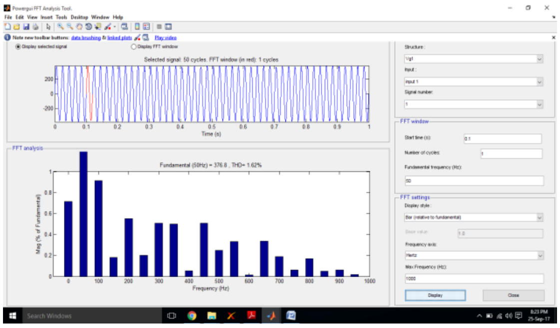


Fig:(a)

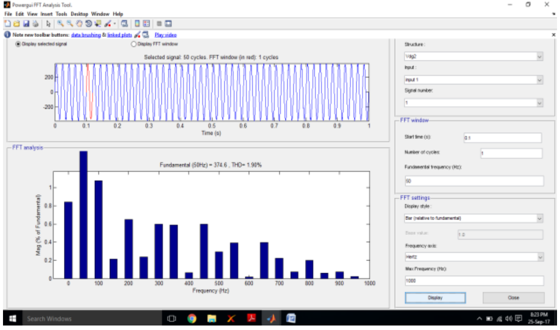


Fig:(b)

Fig:THD waveforms of the isolated design system.

However, since each DGU was designed without considering all the elements interconnected to them, they obtained design is decoupled and the isolated operating conditions have to be verified when interconnected. From this point of view, a better design could be obtained if the complete system model is considered in the proposed design approach.

CASE-2: MICROGRID TEST SYSTEM OF A COMPREHENSIVE DESIGN

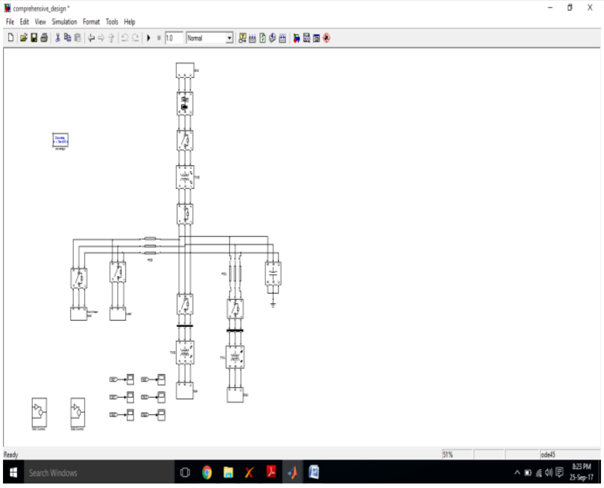
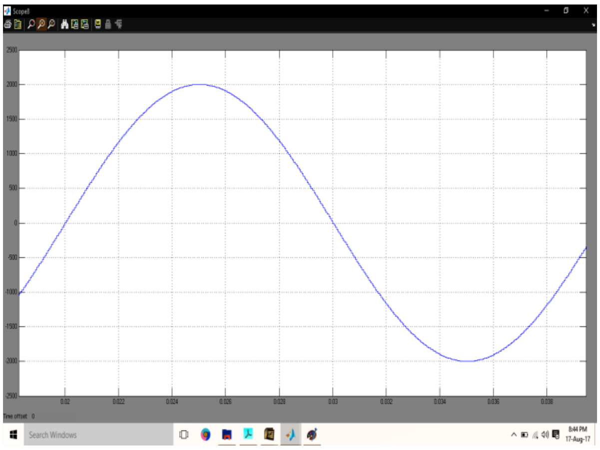
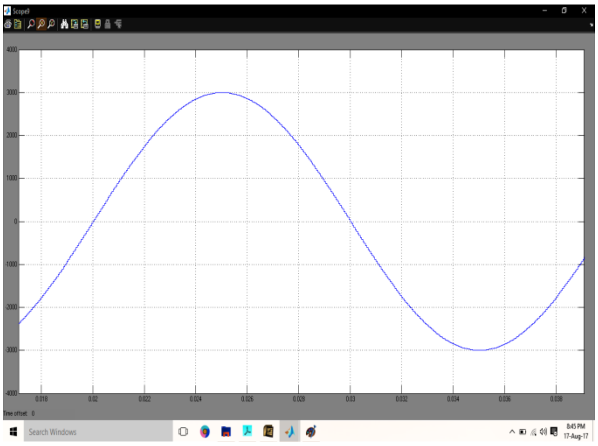


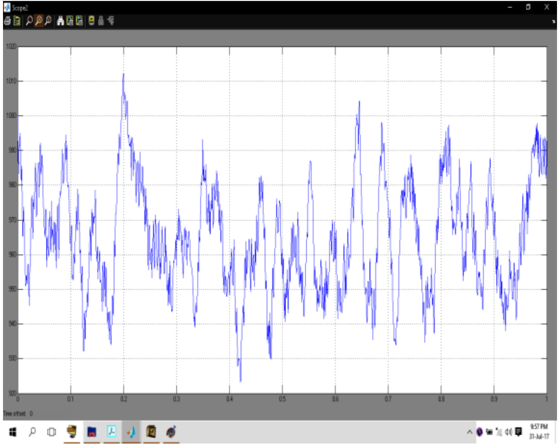
Fig. Simulation diagram of a microgrid test system of an comprehensive design



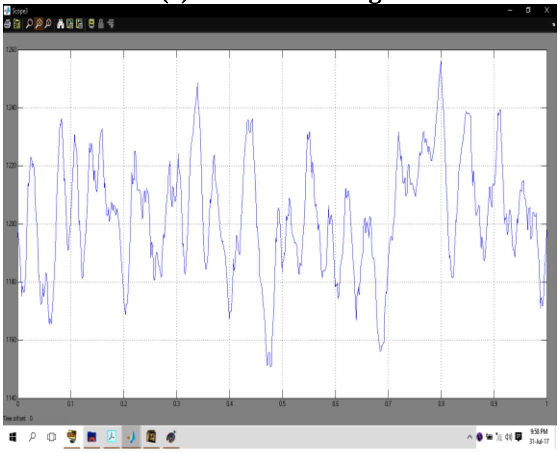
(a) ***DG*1 *i*11 converter current.**



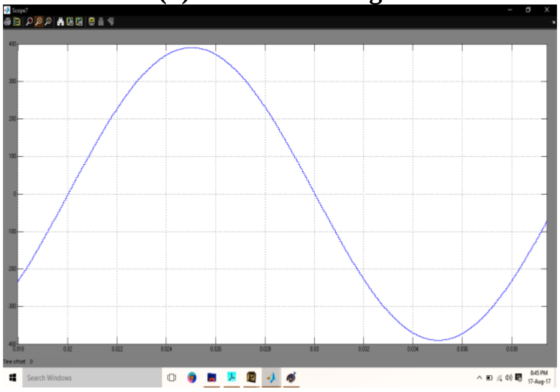
(b) ***DG*2 *i*21 converter current.**



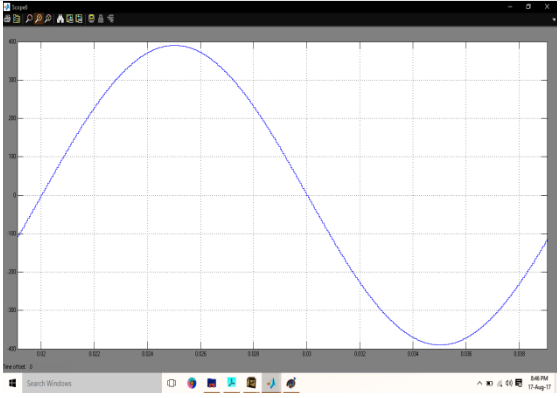
(c) *DG*1 *v*1*dc* voltage.



(d) *DG*2 *v*2*dc* voltage.



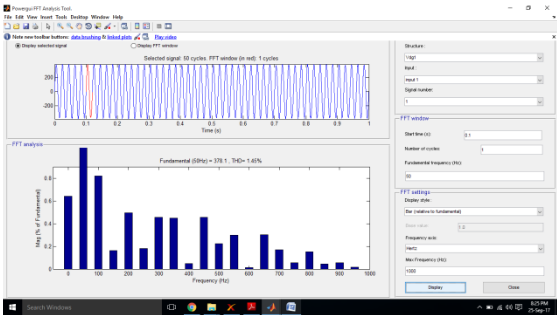
(e) *DG*1 node 1*A* voltage.



(f) *DG*2 node 2*A* voltage.

In this case study, the design of both DGUs is performed simultaneously, considering all the elements interconnected in the microgrid, using the overall model derived for the system of Fig. As in the previous case, these DE results are used to perform matlab/simulink simulations of the test system in order to validate the design. Fig. 6.5 shows some matlab/simulink simulated waveforms of *DG*1 and *DG*2 when connected to the test system, considering the DE results. As in the previous case study, the matlab/simulink simulation validates the obtained results and the proposed design approach. The results of both case studies show a remarkable performance of the proposed design approach. Multiple and diverse DOref are closely met, while the grid side power-quality standards are easily fulfilled with a very reduced converter current ripple; even in the presence of low switching frequencies and harmonic loads, with the best efficiency possible.

In both design Case Studies, the performance of each DGU is seen by the network almost as an ideal harmonic free voltage source and prevents any harmonic related issue in the network caused by the operation of the DGUs. For this reason, the overall performance of the system and the obtained DE are very close in both case studies.



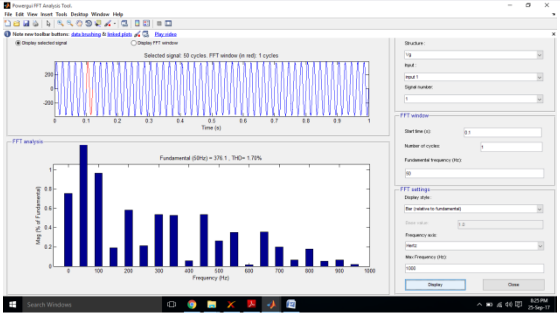
Powergui FFT Analysis Tool.

Selected signal: 50 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 378.1 , THD= 1.45%

Structure : Vdg1
Input : input 1
Signal number: 1
Start time (s): 0.1
Number of cycles: 1
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Frequency axis: Hertz
Max Frequency (Hz): 1000

Fig:(a)



Structure : Vg
Input : input 1
Signal number: 1
Start time (s): 0.1
Number of cycles: 1
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 1000

Fig:(b)

Fig.: THD waveforms of the comprehensive design system

IV. CONCLUSION

Based on the modeling proposals mentioned above, several applications were proposed to show the benefits and capabilities offered by the system modeling. The Exact Design (ED) methodology for the selection passive component values, based on the fulfillment of power quality indexes was introduces. This methodology is based on the also introduced computation of steady-state modulation parameters (CMMPS) methodology which allows the obtaining of the required modulation parameters form which the VSC-based system behaves under certain desired operating conditions. This project has introduced a novel design methodology based on optimization and the system design system for interconnected distributed generation units (DGUs) in which the harmonic distortion and its effects over multiple design objectives are explicitly considered. The design results of the presented case studies have shown a remarkable performance when both, the grid parameters are available and not available, offering an excellent power quality with the best efficiency possible in the presence of low switching frequencies. Compared with other design methodologies, this proposal offers an advanced performance, which relies on the comprehensive consideration of multiple design objectives.

FUTURE SCOPE

The present study is performed with two inverters having identical anti-islanding mechanism. In a high penetration PV case, inverters with distinctly different anti-islanding mechanisms may be operating in parallel. Such a scenario needs to be studied to evaluate the interaction of the different anti-islanding methods and their efficacy when used in parallel. With an increasing PV penetration level, it becomes imperative to analyze the impact of PV generation on the sub-transmission system. During a power ex-port scenario the distribution system behaves like a generating source, which has both single phase, and three phase generation with a power electronic interface. Developing suitable models of these sources and studying their impact on the sub-transmission system could be an interesting research avenue.

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