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Renewable Energy Based Grid Connected Inverter to Improve Power Quality

A Balamurugan, R Sumathi

Abstract: Alternative to conventional energy source, Renewable Energy Resources (RES) plays a vital role to handle nonlinear-load in the power system network. Many renewable sources are available for present days. Renewable energy sources may be a solar, wind, and fuel cells, which depend upon the distribution voltage levels. The depletion of fossil fuels, RES is an alternative source to meet the demand at the load side itself. In this paper, RES is used to handle the current (I) based, and voltage (V) based power quality problems in the utility side. A shunt and series switched multi-function grid-connected inverter (SSMFGCI) is introduced to minimize the power quality problems. The SSSMFGCI is connected to the grid by series or parallel combination to compensate the harmonics current or voltage. To prove the concept of the proposed method MATLAB/SIMULINK software is used.Atmega328 based reduced rated hardware is developed for verifying the system enhancements.

Index Terms: Distribution system (DG), grid-connected inverter, power quality improvement, SSSMFGCI.

I. INTRODUCTION

Electric demands are increasing day-by-day due to technological improvement. Most of the utility loads are satisfied by fossil fuels only. Due to the firing of fossil fuels increase atmospheric pollution and increase climatic change all over the world. The main advantage of the RES is that there are no fuel cost concerns, but in conventional sources, fuel cost is the major issues to increase the utility demand rate. The traditional electric grid is generating power from one side and transmits power to the distribution side. Long transmission of power from the generation side to the distribution side causes power losses in the network. So it can be overcome by renewable energy sources. By proper handling of RES at the distribution side, it doesn't need that much effort to meet the utility demand. The main aim is to minimize the power loss in the system. MFGCIs are connected to the grid to achieve power conversion of DC to AC or AC to DC applications includes solar, wind and fuel cell. MFGCI is used to compensate current based and voltage based power quality issues.

In [1] presents the injection of harmonic current at Point of common coupling using static distribution compensator (DSTATCOM) to reduce voltage sag. In [2] discussed a load sharing technique to reduce harmonic current without mutual communication. In [3], a wireless controller is used in power inverters in the distributed generation system. In [4] the general objectives of power quality issues and interconnection of power converters in the distribution side are discussed. By using active power filter (APF), they eliminate harmonic current in the 3 phase 4 wire system with RES [5] and [6].

The paper is organized as follows. In section II, a detailed study of power quality problems are discussed. In section III, the proposed SSSMFGCI inverter, modes of operation is presented. In section IV, grid interface inverter is discussed. In section V, discussed a system description and concludes this paper.

II. DETAILED STUDY OF POWER QUALITY PROBLEMS

From the utility side, the loads are classified into two categories. They are linear and nonlinear loads. The power quality problems are mainly caused by the connection of unbalanced load in the power system.

In the DG side the power quality problems are overvoltage, distortions, harmonics, flickers, power factor (leading/ lagging); unbalance voltage and reactive power demand.

Table.1. listed the categories of power quality problems in the DG side. They are classified based on the harmonic contents present in the power system. The power system transients may occur as short, or long durations depend upon the disturbance. The power factor may also consider because the load may be inductive or capacitive loading. For inductive load, the power factor is lag, and for capacitive load, it leads the voltage. From the next category, voltage imbalance is listed. In this type, the voltage may occur as sag/swell in condition. The frequency disturbance occurs at low phenomena. The electromagnetic interference is mainly caused by the interaction of electric and magnetic fields and high frequency. It depends upon the communication lines interfere with the transmission lines.

The active power filters, which eliminates the harmonics by connecting both shunt and series combination to reduce the power factor correction, harmonics filtering. Due to the presents of nonlinear loads connected at the distribution side, the active filters are connected at the Point of common coupling (PCC) to decrease the current and voltage harmonics and also used to improve the voltage stability in the power system networks.

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* Correspondence Author (s)
A Balamurugan Assistant professor, V.M.K.V Engineering College, Salem, Tamilnadu .
R Sumathi, M.E Power systems engineering, V.M.K.V Engineering College, Salem, Tamilnadu.

Table 1: Categories of Power Quality problem (DG)

Power system Harmonics	Power system transients	Power factor	Voltage imbalance	Frequency disturbance	Electromagnetic interferences
Waveform distortion Produce low frequency	Occurs fast and short peaks Produce distortions like notching, peak overshoot	Inductive loading of lag Power factor.	Voltage sag/ swell.	Low-Frequency phenomena.	Interaction between electric and magnetic fields. High frequency

III. CONVENTIONAL ELECTRIC GRID

Traditional electric power system consists of generation, transmission and distribution. The loads are connected in the utility side. It is classified into two types

i. Linear loads
ii. Non-linear loads.

The non-linear load is the major problem to develop the harmonics in the grid system. Due to the harmonic presentation in the grid the voltage will fall down or increased. The main drawbacks of the conventional energy sources are:

- Poor power factor
- Increase harmonic current and voltage
- Unbalanced loading condition the grid gets disturbed
- Total Harmonic Distortion (THD)
- Stability
- Does not meet the high demand.
- Disturbs voltage regulation.

To eliminate the above drawbacks from the conventional energy source Renewable Energy Sources (RES) grid-connected inverter is used.

Inverter Control

The regulation of dc voltage to the grid-interface inverter is depends upon energy available at the source side. It depends upon the exchange of active power into the grid.Fig.1. Shows the RES connected grid-interconnected inverter. The current control circuit is taken current reference from the grid and it is given the switching pulse to the grid interfacing inverter. The dc link voltage is controls and extracts maximum power from the RES. Thus the compensating current is fed to the grid with the help if grid-connected inverter.

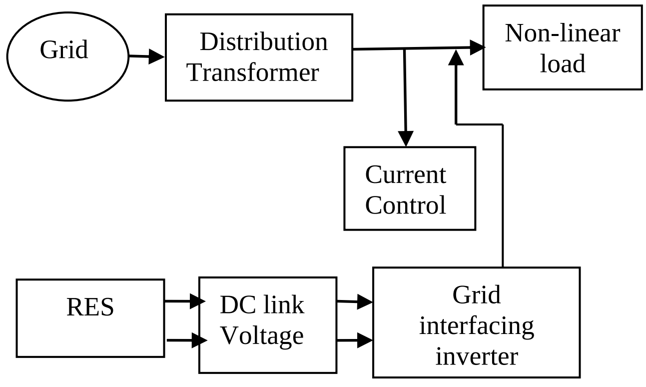

Fig.1.RES connected grid-connected inverter

IV. GRID INTERFACE INVERTER

The current controlled VSI and APF are incorporated in the grid interface inverter. The function and operation of the 4-leg grid-connected inverter are listed below.

Functions of Grid Interface Inverter

- Support active power from RES to grid.
- Support the reactive power load to compensate for lead/ lag power factor problem.
- To compensate the harmonic presents in the system.
- In the case of balanced circuit, neutral current and current unbalance is compensated.

4-Leg inverter

- Non-linear load presents the system gets unbalanced. To reduce the unbalanced loading, the GCI is used.
- To maintain the desired output voltage and the desired output waveform at different loading conditions.
- It is optimal applications like Electronic communication, industrial automation, and military equipment, which give the high performance of UPS.

V. PROPOSED SYSTEM

In the Distributed Generation (DG) the inverter circuit which interfaces RES to the grid. The inverter circuit is the voltage source inverter (VSI) is connected parallel to the network. Fig.2. shows the block diagram of the proposed SSSMFGCI method connected at the distribution side.

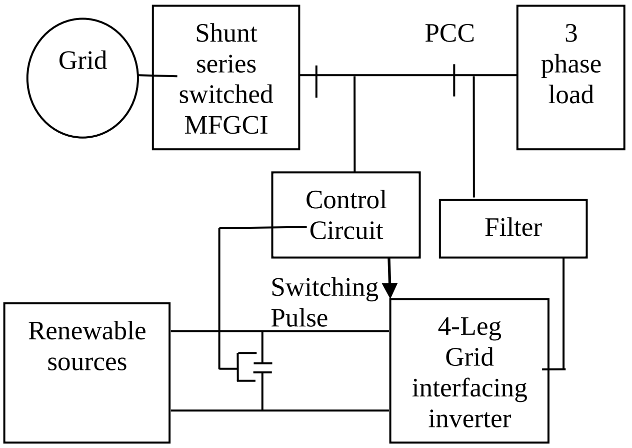

Fig.2: Block diagram of the proposed SSSMFGCI method.

To eliminate or reduce the harmonics current or voltage in the distribution system, an SSSMFGCI proposed in this paper for better results. Fig.3. shows the proposed configuration of MFGCI.

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The main aim of the SSSMFGCI is used to eliminate the harmonics produced from the utility side.

The filter circuit is directly connected to the grid at the Point of common coupling (PCC) to eliminate the harmonic frequency presents in the infinite impedance bus. Thus it has to compensate voltage and voltage imbalance in the grid system.

The overall feedback loop is used to control the desired voltage value. The filter and control block is connected to a 4-leg grid-connected inverter. The inverter switch control is controlled by the control block to get the output voltage and also a filter is used to eliminate harmonics presents in the system.

The harmonics are integer multiples of fundamental frequencies, that combine with the essential voltage or current, and the produce waveform distortion. Nonlinear loads denote it. Lower order harmonic is closest to the fundamental one, and its amplitude is greater than or equal to 3% of the primary element.

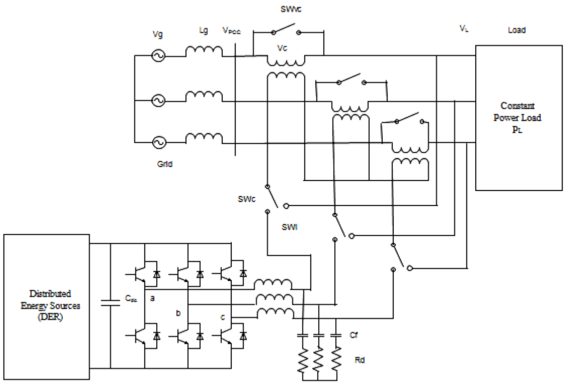

Fig.3 Proposed configuration of MFGCI

VI. SYSTEM DESCRIPTION

There are four different modes of operation in SSSMFGCIs system.

Mode A: SSSMFGCI that converts distributed energy sources produce DC power to AC power to grid.

Mode B: In this mode, to compensate the I-based power quality issues in the grid. The minor secondary voltage power quality issues may also be reduced. The switch Swt, Swi is closed, and Swv is open in condition. The active power is injected into the system to minimize I-based power quality problems. The SSSMFGCI is shunted to the grid.

Mode C: In this mode, the V-based power quality problem is focused. The inverter is connected in series to the grid to reduce V-based power quality issues. In this mode C, S_{Wt} and S_{Wi} switches are opened, and S_{Wv} switch is closed.

Mode D: In this mode, the inverter acts as an UPS. This mode is operated under severe power quality problem occurs. The inverter is used to reduce balanced and unbalanced load presents in the load side to mitigate voltage sag / swell problems. It is used to reduce the V and I harmonics present in the system by connecting inverter in series and parallel combination.

In this paper, the inverter is used to compensate for the unbalanced loading cause's voltage sag /swell issues. The performance of the inverter is on four different modes of operation.

Table 2 shows different modes of operation of SSSMFGCI. In Mode A, SSSMFGCI that converts DC power to AC power for the grid. In mode B, a current or voltage based power quality problem is reduced. In mode C voltage based power quality problems are reduced by connecting SSSMFGCI in series to the grid. In mode D it operates as an uninterrupted power supply (UPS).

Table.2: Modes of operation and functions of SSSMFGCI

Mode	Configured	Switches			Functions
		S_{wt}	S_{wi}	S_{wv}	
A	Parallel	Active	Active	De-active	Conventional Grid connected the inverter power flow
B	Parallel	Active	Active	De-active	Low voltage and current problem.
C	Series	De-active	De-active	Active	Causes voltage problem at a high level.
D	Parallel	De-active	Active	De-active	UPS (uninterrupted power supply)

VII. SIMULATION RESULTS

Software description: To prove the concept of the proposed circuit is tested using MATLAB Simulink and Sim Power System tools. Due to the presence of unbalanced loading in the grid system, they may cause voltage sag/ swell problems. This problem is considered for validation in the proposed method to get better results for understanding.

A three-phase supply voltage of 415V is supplied to the sensitive demand. Due to the presence of 3 phase fault, voltage sag is created. The fault is turned on during the time of 0.15S to 0.25S. Voltage sag causes so many problems and causes the load to get damaged. So to avoid damages in the sensitive load, SSSMFGCI is activated during the interval when voltage sag is detected. This is done by the controller. This voltage sag is compensated due to the presence of SSSMFGCI.

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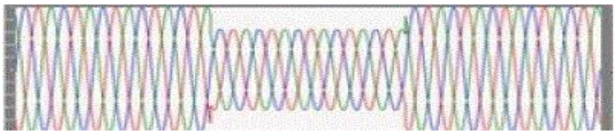
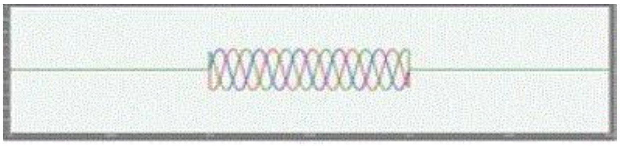
A grid-connected RES with a 3-leg inverter is modeled to represent as a dc source. Fig.4 shows the mat lab Simulation result for Voltage and Current Injection.

In Fig.4 (a) shows the grid voltage in this mode of operation, there is no disturbance in the grid after a few seconds there is the oscillations or disturbance presents at the network. The grid interfacing inverter is not connected to the grid in this case current is similar to the load current.

In Fig.4 (b) shows the injection voltage to the grid. Thus the disturbance is compensated at the grid. Simultaneous load enhancement and power injection are achieved in this mode.. The inverter is ready to handle reactive power and output voltage remains constant. This is shown in Fig.4 (c) voltage across the load after compensation. There is no disturbance in the load voltage, and the waveform has no disturbance in it.



(a)



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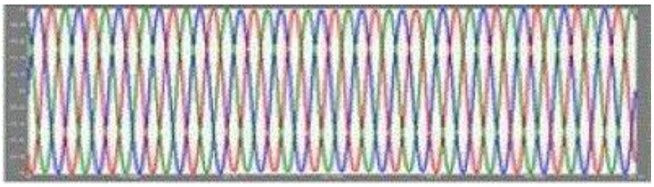


(c)

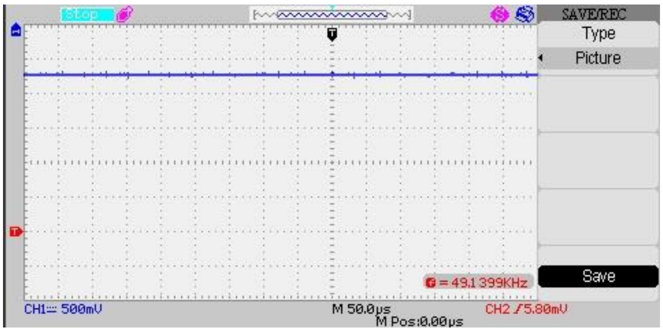
Fig.4: Mat lab Simulation Result for Voltage and Current Injection (a) Grid Voltage (b) Injection Voltage (c) Voltage across load

Hardware description:

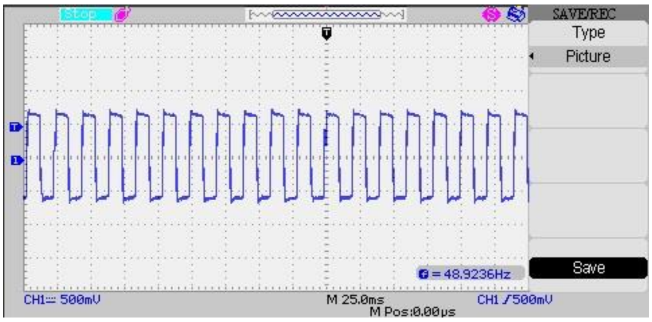
Reduced rated hardware is developed to prove the proposed circuit diagram. 10W solar panel is used to generate injected power. The injected power is directly connected to converter or stored this energy in battery. In this circuit, the generated power is stored into 12 V batteries. Hence battery is used to store energy from RES. It is required to injected power for the converter. 3-phase 3-leg full bridge inverter is used to convert dc to ac. IRF5V0 MOSFET's are used to construct full bridge inverter. Serially connected 1:1 injection transformer is used to support voltage.

12-230V injection transformer is mainly used to inject current to grid and it is connected in parallel to the grid. ATMEGA 328 controller is used to generate the firing pulse. TLP250.

MOSFET driver is used to drive the MOSFET. Fig.5: shows the hardware Results. Fig.5 (a) shows the dc source voltage. This voltage is taken from the PV source. Fig.5 (b) Voltage across secondary of Current Injection Transformer at Current Injection Mode .Fig.5 (c) Voltage across secondary of Voltage Injection Transformer at Voltage Injection Mode Fig.5 (d) shows the Grid Voltage Fig.5 (e) shows the voltage across the secondary of current injection transformer at current injection.



(a)



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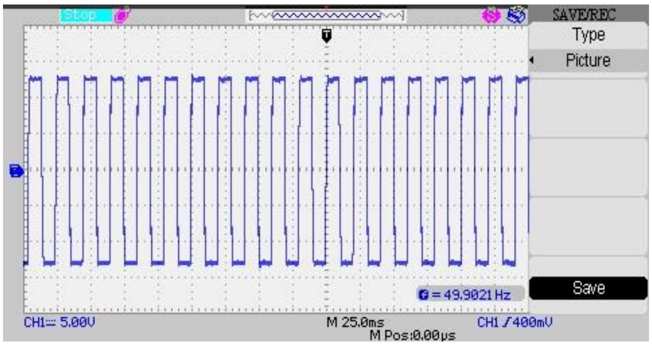

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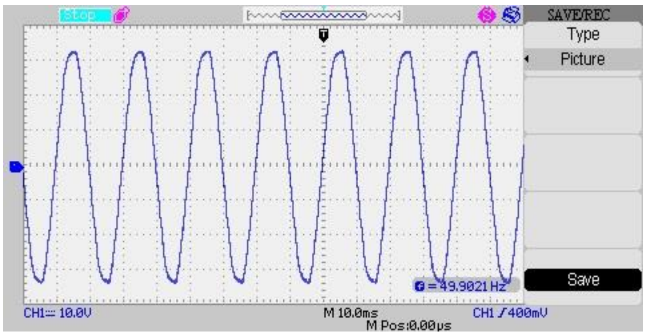

(d)

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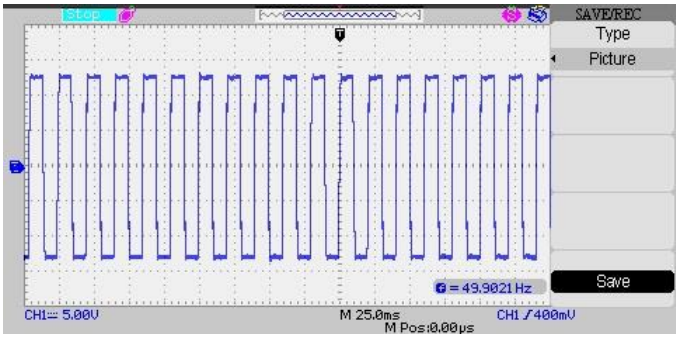

(e)

Fig.5: Hardware Result (a) DC Source Voltage (b) Voltage across secondary of Current Injection Transformer at Current Injection Mode (c) Voltage across secondary of Voltage Injection Transformer at Voltage Injection Mode (d) Grid Voltage (e) Voltage across the secondary of current injection transformer at current injection mode

VIII. CONCLUSION

The proposed SSSMFGCI is compensating both V-based and I-based power quality problems. The proposed inverter can be connected in both series and parallel combination to the grid. According to various grid disturbances in the grid system the inverter switches are used as bidirectional, and they can be operated at different mode of operation. By using one inverter without overrating, both voltage-based and current-based power quality issues are compensated. In the shunt connected inverter, the current harmonics are eliminated, and series connection voltage harmonics are eliminated. This paper also presents different modes of operation and control scheme for compensation of power quality issues. The simulated results are used to prove the concept of proposed SSSMFGCI. Reduced rated hardware was developed to validate the circuit, and the results are satisfying.

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AUTHORS PROFILE

A. Balamurugan is completed Master of engineering in applied electronics, Anna University, Chennai. B.E in Electrical and Electronics Engineering, Madras University, Chennai. Diploma in electronics and communication engineering in Director of technical education, Chennai and currently working as Assistant Professor in V.M.K.V engineering college, Salem.

R.Sumathi is pursuing Master of engineering in power systems engineering from the department of electrical and electronics engineering, Vinayaka mission's university, Salem., B.E degree in Electrical and Electronics Engineering, madras university, Chennai, Diploma in electrical engineering in the director of technical education, Chennai.

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