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Harmonic Voltage Measurements in a Single House Microgrid

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Abstract

In this paper, we will discuss about the harmonics measurements of suchsmall microgrid which are part of single house along with their impacts on the supply voltage waveform. The voltage harmonic magnitudes are compared between two operation states along with the relevant standards. We will be presenting the 10 minuteand 3 second average values. When compared to the grid connected mode, the harmonic voltage magnitudes are higher in the islanded mode itself and also the difference between 10 minute and 3 second average value is greater. In some cases themagnitudes of individual harmonics or the total harmonic distortion go beyond the limits. In most of the cases, the 10-minute average values will be enough to evaluate the harmonic distortion levels, however we cannot see any variations unless we usethe 3 second average values.

Keywords: Solar PV Array, Boost converter, Inverter, Non linear loads , Harmonics

1. Introduction

A microgrid is a group of interconnected energy network uses a distributed energy resources that involves solar panels, energy storage system, wind energy and combined heated power plants. That means the energy generated is closer towards needed. Microgrid which can be connected to larger centralized grids can be function as Supporting or operate independently providing with secured backup when there is in need. And these distributed energy resources are great way, they generate clean renewable energy and holds business and buildings cancome more energy independent. Tapping into flexible and reliable energy supply, which reduces the greenhouse gas emissions. Micro grids are more efficient, they also save on fuel energy cost. This project describes about solar Energy based generation which is clean and pollution free, maintenance free operation. But however, the main important factors which limits the installation of PV system is, as they are intermittent in nature and lower efficiency. Inorder to increase the efficiency of PV system, a

Maximum power point tracking is used to extract the maximum power from PV module and deliver to the load.

Microgrid: Microgrid is a small independent energy grid and low voltage distribution network. It comprises various distributed generations, energy storagesystems, loads and controldevices. A microgrid utilizes the renewable energy sources for the generation like PV modules,wind turbines, hydro etc. micro grids are capable for operating with traditional grid (Grid connected mode) or independently (Islanded mode) without change in power quality. It poses the advantages of reduced transmission losses compare to conventional generation and can be able to operate in above two modes. The islanding mode occurs when the micro grid is disconnected from the traditional grid under failure.

Type of sources in Microgrid: In the microgrid we can generate the power from Sun, Wind, Hydel, Fuel cell and Other energy resources. In this project we are working with solar based microgrid. Generally, two types of sources can be used for our houses i.e.; Solar and Wind power. But we choose solar over wind because they produce mechanical vibrations and noise. Thus, we use Solar energy which do not have such issues. Few other benefits of solar energy generation are that it requires low maintenance and it is environment friendly.

Challenges in Microgrid: The major issues of microgrids are; Maintaining voltage profile, Stable interconnection with main grid, Storage of energy using energy storage unit at off peak load.

2. Literature Cited:

The design of the boost converter's closed loop control is covered in this paper using predetermined criteria. The average model is controlled by the closed-loop boost converter, which transforms low-level DC voltage that is supplied from a direct current power source. The typical model is helpful for analyzing the converter's dynamic behavior when its operational parameters are altered. Hand calculations including theory and simulation will be part of the design technique. the simulation performed using Pspice.[1] A performance evaluation, which discusses and achieves associated output voltage, current, and power waveforms, includes the closed-loop operation of the average model. An average model that closes the loop to boost converter has been developed in this paper.[2] A simulation of the entire system in PSpice produced reliability at full capacity as indicated by the data. Since the power phase has an effect of the architecture at low frequency and employing a compensator, is adequate, utilizing correct the amplifier makes the adjustment of the boost converter a lot simpler, substantially simplifying the design process. [3] Additionally, the controller has the ability to maintain the output voltage while the load changes. This paper focuses on the most effective way to change the inverter gain is to include PWM control in the inverters themselves. It is useful because it is simple to use, dissipates less power, has linear amplitude control, and is affordable. PWM is used in a wide range of applications, from power control and conversion to measurement and communications. To broaden the scope of the approaches' potential uses, more research is now being done.[4] A potent method for regulating analogue circuits using power provided to a load is pulse width modulation. PWM is a technique for digitally recording the levels of analogue signals. The ratio (ton/T), wherein T is the time in seconds, is the definition of duty cycle. PWM techniques include sinusoidal, squared wave, trapezoidal, stair-case, the delta, δ-sigma, space vector that results from harmonic injection, and third harmonic PWM techniques. These techniques are used for a variety of applications. PWM approaches seek to reduce harmonics while improving controllable output voltage. The short circuit capacity of the network they are being introduced into determines the current harmonic limitations. In essence, the customer is permitted to inject more the more harmonic currents the system can tolerate.[5] The maximum harmonic current that a customer may introduce into the utility system is specified by the harmonic current limits. The utility is in charge of giving the customer a pure (low distorting) voltage. However, the customer must comply with the harmonic current restrictions in order to accurately evaluate the utility. If not, the consumer could be held accountable for creating the voltage distortion themselves. Due to their ability to control power flows from both generators and storage devices for energy, inverters are the primary

operator in maintaining control of AC microgrids. Grid supplying inverters, grid forming inverters, and grid supporting inverters are the three main types of inverters, which vary based on the control method. Different hardware topologies can be used to create those inverters, and each has benefits and drawbacks.[6] This article provides a summary of the popular inverter topologies used in AC microgrids. This paper also discusses the primary control techniques and inverter layouts. Since they specify how the energy resources' power, both active and reactive, flows. Consequently, a summary of the inverter types and popular architectures for microgrid purposes has been provided in this study. Grid forming, grid following, and grid supporting are the three different types of MG inverters. By following the sinusoidal voltage that exists in the AC bus, grid-following inverters feed powergenerated by renewable energy resources into the grid. [7] The grid forming inverter forms thesinusoidal voltage that exists in the AC bus during islanded operation, and by pumping or consuming power from the AC bus, it regulates the desired voltage frequency and magnitude.[8] Inverters that form a grid are therefore linked to ESDs. Last but not least, grid- sustaining inverters, which are connected to portable generators or ESDs, assist grid- forming inverters in maintaining the alternating current (AC) bus voltage within the parameters established by the quality requirements.[9] Different topologies can be utilized to create inverters. In recent years, there has also been a rise in demand for multilevel inverters, one of whose popular topologies is the cascaded H-bridge inverter. However, due to their extra capabilities and benefits, various inverter topologies have captured the attention of MG researchers. These topologies include matrix inverters, two-level current-source inverters, and four-leg voltage-source inverters.[10] The micro-hybrid electrical system is anticipated to be used in the proposed study to realize an ideal micro power system. Due to the natural variations in wind and solar irradiance, the integration of solar and wind energy into the distribution power grid results in various dynamic transient issues. This can be accomplished by utilizing numerous controlling devices, such as MPPTs, to track the greatest amount of power and also modify the rate of duty cycle for a boost converter switch, VSC control systemto preserve unity power factor as effectively as to keep dc link voltage and provide pulses for switching to the inverter. Where there exists a decrease, only electrical power from the grid is used. [11] The system is set up to employ the available electricity from sources that are renewable to the load. In photovoltaic (PV) systems, MPPT (maximum power point tracking) is used to continually maximize the power output from the PV panel. Because of the atmosphere, the panel's power output is not linear [12].

3. Working Model:

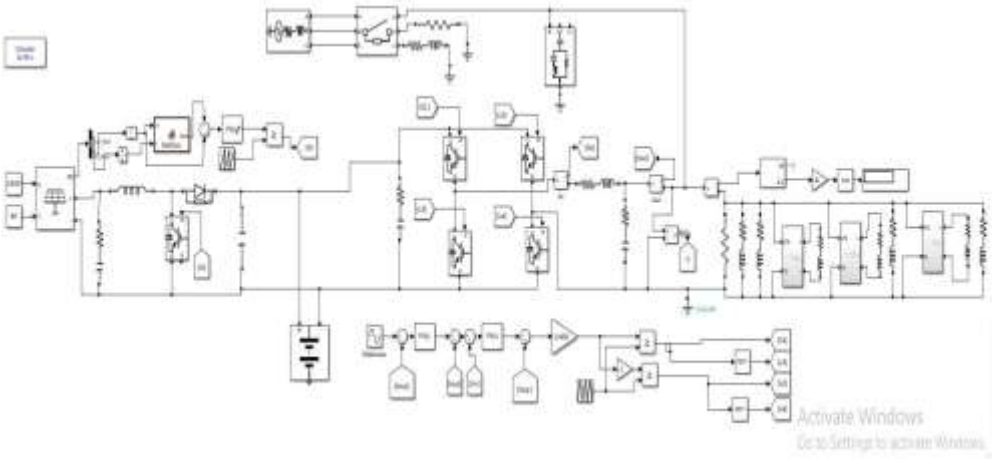

Figure 1: working model

4. Components Description:

4.1 PV Array:

PV Array is a series and parallel combination of solar panels to get required voltage and current based on our applications. Solar panel is a combination of series and parallel solar modules. Solar module is formed with the interconnection of solar cells mountedon a structure. The solar cell is also known as photovoltaic cell which converts solar energy into electrical energy. The energy from the sun is trapped and given to loads. The power rating of PV array is obtained as 7200W.Hence the final design of power rating of PV array can be done at 8000W rating for better capabilities and availability in market.

4.2 Boost Converter:

Boost converter is used to step up the input voltage, so that the output voltage is higher than the input voltage. The output voltage in solar is less than the required voltage but the inverter requires 400v for its working. In order to increase the voltage, we use boost converter. This is used to step up the DC voltage from the solar panel. In this Converter we use MPPT algorithm-based switching action. MPPT algorithm is used for to track maximum power from the solar radiation and it is given to the boost converter. The output obtained from boost converter is 400v. In the controller, the bus selector is used to acquire multiple inputs from measurement block of PV array. The unit delay block used for make a specified delay in input signal. MATLAB function is the block where the MATLAB P&O code is dumped for the system execution. The Sum block is used here for the comparing the difference between actual PV voltage with the MATLAB Function Block output voltage. The Proportional-Integral (PI) Controller is the continuous time controller which converts the voltage difference output of the sum block to the required Duty Ratio for the switching. To convert this Duty Ratio to the required PWM signal, this duty ratio is compared with the triangular wave (Repeating Sequence) using relation operator. Whenever the duty ratio is greater than magnitude of triangular wave at that time, the pulse will be generated with same duration inthe output.

4.3 Inverter

The inverter converts the Direct Current (D.C) into Alternating Current (A.C) power. The current produced by a solar panel is DC and the current which we require for house loads is AC. So, to convert this DC to AC we require an inverter.240v AC is given to house loads. Current loop control PWM technique is used in the inverter. This technique is basically a closed loop control system where external voltage loop and internal current loop is measured. By taking this as a reference the gain isimproved and switching action takes place accordingly.

4.4 House Load

House load basically comprises of linear and non-linear loads. The appliances that comes under non- linear loads are LED bulbs, Television, Refrigerator, Washing machine, etc. The appliances that comes under linear loads are Heaters, Incandescent lamps, fans, etc. The nonlinear loads produce harmonics Because the pulses distort in the current waveform this will generate harmonics that create disturbances in the system. The load modelling in this model is done by using the series RLC Load block of MATLAB Simulink. All the specifications importedinto that load blocks and connected to the supply through a Current Measurement block as shownin the above figure. The LED Bulbs, TV and Washing machine Loads are designed as non-linear loads of house.

4.5 Battery

Batteries are generally used for storage of energy for some time and we can use this stored energy whenever it is necessary. Batteries play key role in the microgrid systems as there is onlyfew small sources. Battery designing plays a major role in the power systems. Incorrect designing will lead to the improper working of the system. There are different types of batteries available in the market for household use. They are: Lead- Acid Batteries, Lithium-ion batteries,Nickel- Cadmium batteries. In the above battery types, the Lead Acid batteries are widely used due to its rigidness and overcharge capability. In the model, for ease only one battery with same ratings is used. But in practice, there is availability of only 24V,30Ah batteries. Hence 17 batteries of 24V,30Ah batteries are to be connected in series to acquire

the required rating. The battery response time is set to 0 or 1 for quick response to the changes in the system parameters.

4.6 Grid Connection:

The components of this Grid connection Module are:Three- phase voltage source, Three-phase circuit Breaker Series RLC Load Three- phase Harmonic Filter. The three phaseAC voltage block indicates the Main Grid / Utility grid supply. This supply in practice comes from the interconnected Grid network which has various types of supply sources connected to it.This three-phase source indicates the voltage level after the secondary distribution in the main power system Grid i.e., Output of the distribution transformer at the load end of the power system. The three phase circuit breaker is a device which acts as a High Voltage switch. It turns ON/OFF the Grid supply to the Microgrid whenever it is necessary. The Circuit breakers can be manual operated or Automatic operation. In general, it made to work as automatic In MATLAB, the switching time depends on the simulation Run time. The harmonic filter is the Resonant circuit which is used for filtering of the unwanted harmonics in the connected system. There are mainly two types of harmonic filters namely Active filters and Passive filters. The active filter has the comparator circuits whereas the passive filter uses combination of R,L andC parameters. In the MATLAB, there is passive filters used.

5. Specifications

5.1 Inverter:

Input voltage of inverter = 400v DC

Output Voltage of inverter = 240v 50Hz AC Filter Capacitor

(Co&Rc) = (16.57 µF, 4mΩ)Filter inductor (Lo&Ro) =

(1.414mH,1mΩ)

Input Capacitor (including internal resistance) = (500µF, 1mΩ)

5.2 House loads:

Fan = 240W; Tube light = 120W; LED Bulb =40W; TV = 100W; Refrigirator = 140W;Washing machine = 500W; Mixer = 600W; Heater = 2000W

5.3 Boost Converter:

Input Capacitor (including internal resistance) = (1000µF, 0.1mΩ)Filter Capacitor (Co) = (0.78125mF)

Filter inductor (Lo) = (5.625mH)

Input voltage of Boost converter = 130-170V

Output Voltage = 400VRated power = 8KW

6. Working:

Solar energy is used to produce electrical energy. The energy from the sun is trapped andgiven to loads and at the same time the excessive energy is saved in the batteries (as a backup). The output voltage in solar is less than the required voltage, the inverter requires 400v for its working. In order to increase the voltage, we use boost converter. This is used to step up the DC voltage from the solar panel. In Boost Converter we use MPPT algorithm-based switching action. MPPT algorithm is used for to track maximum power from the solar radiation and it is given to the boost converter. The output obtained from boost converter is 400v. A 400v 30Ah capacity isgiven to the battery for the storage of power.

All household loads are AC but the output we obtain is in DC. Thus, we use an inverter and convert 400v DC to 240 AC voltage. This 240v ac is given to households. Current loop control PWM technique is used in the inverter. This technique is basically a closed loop control system where external voltage loop and internal current loop is measured. By taking this as a reference the gain is improved and switching action takes place accordingly.

LC filter is used to improve the output waveform and to reduce the harmonics. Here we have modeled the RL loads in which the active power is already present and reactive power needs to be calculated. After the calculations the load is taken equivalent to the calculated reactive power Basically, nonlinear loads such as LED bulbs and washing machines are present in homes which require rectifiers. Battery that we use generally use for household applications is lead acid battery.

7. Results:

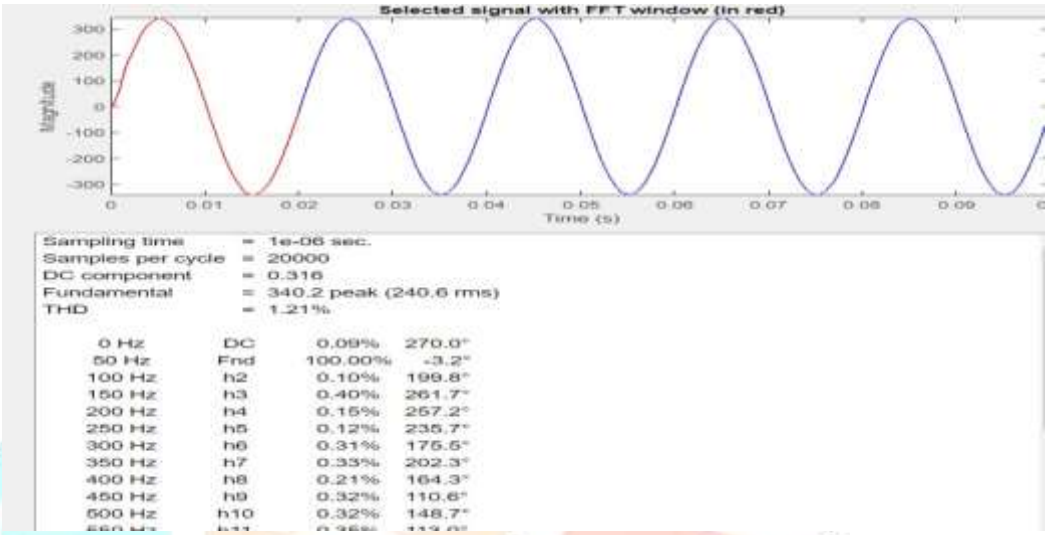

Fig 7.1: FFT analysis of Load voltage with Grid connection

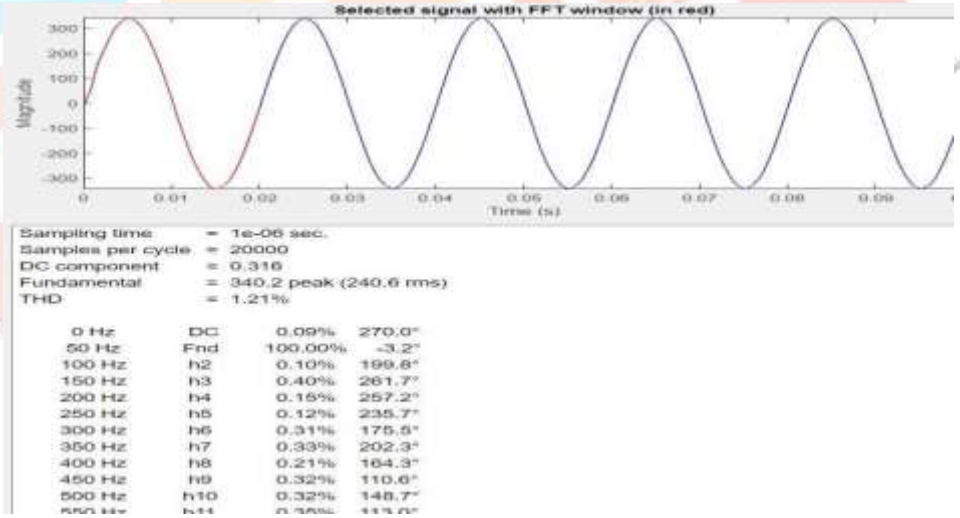

Fig 7.2 : FFT analysis of Output Voltage without grid connection

8. Conclusions:

A simple single house microgrid is constructed by considering Indian context (i.e.,240V AC ,50Hz supply). The comparison of harmonic voltages is done in both islanded mode and grid connected mode operation of the given microgrid. The relation between load variations and harmonics in voltage wave forms are also observed. The output voltage is around 240V rms (or within +/- 5%) and frequency is 50Hz (+/-1%)

even there is a change in solar radiation (400-1000w/m^2) and temperature (25-45.deg Celsius). THD is measured and tabulated using FFT analysis of MATLAB. By introducing non-linear load of house. It is observed that the THD in islanded mode and grid connected mode is around1.21%.

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