Mitigation of Input Ripple Current of Diesel Generator Power Systems

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Abstract- *Diesel generators serves as better backup power, for uninterrupted power supply of electrical energy. The power conditioning system which is associated with their application contains DC-DC Converter stage and a DC-AC inverter stage. In a single-phase diesel genset system, the single-phase inverter introduces a second harmonic component in the current drawn from the diesel genset system source. This low-frequency current ripple has been found to be detrimental to the performance, lifespan, and efficiency of the diesel genset system, if not adequately controlled. The paper presents a single loop current control method for the DC-DC converter stage that reduces the input current ripple drawn from the source in the single-phase diesel genset system. Simulations are carried out using MATLAB; the results compared with the conventional method. To validate the proposed approach, experimental results from a laboratory prototype are presented. The proposed method uses a Digital Signal Processor for control system monitoring and control.*

Keywords- diesel genset, second harmonics current ripple, power electronics, DC-DC boost converter, single phase inverter.

I. INTRODUCTION

HIS In power system non-linear loads are the major source of harmonics. These loads impose various reactive-power demands that may compensate in a manner to improve the power factor and efficiently delivers the active power to various loads. It results in harmonic distortion and relevant problems, for reducing the quality of electrical power and its performance of power system. In this paper, from various equipment's and devices the nature of harmonics that exists in the operation, the ways of eliminating harmonics and its effects have been discussed in this paper. The paper also reviews the strategies and pros and cons of elimination of harmonics followed in the literature and introduced new hybrid optimization methods to eliminate them in multilevel inverters. The hybrid optimization which is proposed a optimum switching angle at a faster convergence rate which may calculate the switching angles and lookup tables were used, which may lead us to find the near optimum switching angle and lower rate coverage.

1. diesel generator

Rice paddies, coal power plant and cattle are huge source of emission, which is continually rising although emission remains well below the global average. India is very vulnerable of climate change, mainly due to the melting of the Himalayan glaciers and monsoon changes too. Our country has pledged a 33-35% reduction of the "emission intensity" of its economy by 2030, as compared to the 2005 levels.

Emergency diesel generators are obtained in many ranges of sizes all based on electricity demand. The units can be installed permanently at fixed locations such as hospitals or can be brought in mobile trailer to outage areas ar disaster sites. The real system made up of diesel engine unit and generating system, electrical switchgear and fuel storage/supply.

A diesel generator is also known as diesel genset, basically it is a combination of diesel engine and a electric generator to generate electrical energy. The diesel engine is designed as to diesel compression-ignition engine to run on diesel fuel, these diesel generators may be placed where there is no connection of a power grid, or as in case of emergency power supply if the system fails, and also used where more complex applications are done such as grid-support, peak-lopping and export to the power grid.

Sizing of a diesel generator is very critical to avoid low-load or a shortage of power. As the modern electronics is complicated the sizing also depends upon the characteristics, specifically and non-linear loads. While size range around 50MW and above, open cycle gas turbine is much more efficient at full load then that of array of diesel engines, and more compact, with comparative capital cost; but even at these power level, regular part-loading, diesel arrays are more preferred for open cycle gas turbine, due to their efficient efficiency.

The combination of a diesel engine, a various ancillary device and a generator, control system, circuit breaker and starting system is referred to as a 'genset' or 'generating set' for short. The size of generator ranges from 8 to 30 KW also 8 to 30 KVA single phase, for house hold and small shop and office with large generators from 8KW up to 2,000 KW, factories or large office works. A 2000 KW set may be housed in 40ft ISO container with tank of fuel, controls, power distribution and all other equipment's needed to be operated as a standalone power station or a standby backup to grid power. These units, referred as power module and genset on large axle triple trailers. The combination of these module are used for smaller power station and these may use 20 units per power section and these section are combined to involve hundreds of power module. In these large six=ze engine and generator or power module are brought to separately connect them together with large cables and control cable to make a complete synchronized power plant. A no. of options are specific needs, including control panels for an autostart and acoustic canopies and main paralleling for fixed or mobile applications, furl supply, ventilation equipment, exhaust systems etc.

Diesel gensets are not only for emergency power, but also have a secondary feeding power function to utility grids even in peak duration periods, or periods when a shortage of large power generation is needed, this program may run national grid. Ships, locomotives also implies diesel generators for power supply, when auxiliary power for lights, winches, fans etc, but also for main propulsion the generators can be placed in a position. Electric drives are employed in many warships which was built during world war II.

1.1 Electrical islanding mode

When one or more diesel genset are operating to connect in an electrical grid are referred as operating in islanding mode. While operating generators in parallel gives us advantage of redundancy, and can provide partial load and better efficiency. The get brings out plant in online mode from the offline mode depending upon the demands of the system given with time. The islanding power plant intended for primary source of power of an islanding community which may often have least three diesel generators, among them any two of them may carry the required load.

Generators can be connected together electrically through-out the process of synchronization. Here synchronization implies matching voltages, phase, current and frequency before connecting to the generator of the system. High short circuit may arise because of failure to synchronize before connection or wear and tear on the switchgear of generator. By an auto-synchronizer the synchronization process is done automatically or manually by the instructed operator. The auto-synchronizer may read the frequency, phase and voltage parameters for the generators and busbar voltages will regulate the speed through the engine governor.

Loads can be share through load sharing and parallel running generators. Load sharing can be gained by droop speed control by the frequency at the generator, while it constantly adjusts the fuel control engine from shaft load and remaining power sources. The diesel generator will take more loads when it is supplied fuel to the combustion system is increased, while the load is released when fuel supply is decreased.

II. DEFINITION OF HARMONICS

Power systems are designed to operate at frequencies of 50 or 60Hz. However, certain types of loads produce currents and voltages with frequencies that are integer multiples of the 50 or 60 Hz fundamental frequency. These higher frequencies are a form of electrical pollution known as power system harmonics. Power system harmonics are not a new phenomenon. In fact, a text published by steinmetz in 1916 devotes considering attention to the study of harmonics in three-phase power system. In steinmetz's day, the main concern was the third harmonic currents by saturated iron in transformers and machines. He was the first to propose delta connections for blocking third harmonic currents. After Steinmetz's important discovery, and as improvements were made in transformer and machine design, the harmonics problem was largely solved until the 1930s and 40s. Then, with the advent of rural electrification and telephones, power and telephone circuits were placed on common rights-of-way. Transformers and rectifiers in power systems produced harmonic currents that inductively coupled into adjacent open-wire telephone circuits and produced audible telephone interference. These problems were gradually alleviated by filtering and by minimizing transformer core magnetizing currents. Isolated telephone interference problems still occur, but these problems are infrequent because open-wire telephone circuits have been replaced with twisted pair, buried cables, and fiber optics.

Today, the most common sources of harmonics are power electronic loads such as adjustable speed drives (ASDs) and switching power supplies. Electronic loads use diodes, silicon-controlled rectifiers (SCRs), power transistors, and other electronic switches to either chop waveforms to control power, or to convert 50/60Hz AC to DC. In the case of ASDs, DC is then converted to variable-frequency AC to control motor speed. Example uses of ASDs include chillers and pumps. The "tradeoff" is that power electronic loads draw non-sinusoidal currents from AC power systems, and these currents react with system impedances to create voltage harmonics and, in some cases, resonance. Studies show that harmonic distortion levels in distribution feeders are rising as power electronic loads continue to proliferate and as shunt capacitors are employed in greater numbers to improve power factor closer to unity.

B Second harmonic ripple current generation in diesel genset based power electronic system

Before explaining the ripple reduction method proposed by this paper, it is important to understand the power electronics circuitry involved with a diesel genset system and the cause of the low order ripple current. The output that can be achieved from a diesel genset is DC. Majority of the electrical loads require AC power for operation, which consequently augments a need for power conversion from DC to AC. A Power Electronic System(PES) is required to produce commercially usable AC power with the fundamental frequency of 60Hz. The diesel genset PES consists of a DC-DC converter connected to a DC-AC inverter which feeds the AC load as shown in Figure 1.

Figure 1. Conventional diesel genset It is noteworthy to mention here that this research aims at low to medium power applications. As most of these applications require a higher output voltage, the Power Electronic System of the diesel genset employs a DC-DC boost converter. The following sections discuss the stages of the PES.

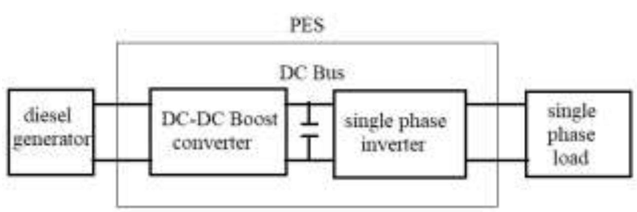

Figure 1. conventional diesel genset PES.

2.1 Boost Converter Stage

Figure 2 below shows a DC-DC Boost converter. A stepped-up output voltage,is produced by controlling the switching of the high-frequency switch, S.

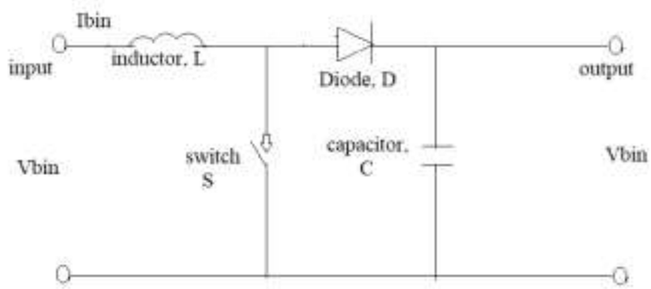

Figure 2. DC-DC boost converter.

The ratio determining the output voltage of the boost converter is expressed here,

$$V_{bout}/V_{bin} = T/T_{off} = 1/1\text{-}D \qquad (1)$$

Where V_{bout} = output voltage of the boost converter

V_{bin} = input voltage applied to the boost converter
T_{off} = switch off time
T = switching period
D = duty cycle

The boost converter switching frequency is kept as 20 kHz. The duty cycle of the converter is controlled by a loop control system. This conventional control system will be discussed here in section 3.

The boost converter input inductor is designed by the equation 2 as below:

$$L = (Vbin * T)/\Delta i * Ibin \qquad (2)$$

Where L = input inductor
Vbin = input voltage applied to the boost converter
T = switching period
Δi = current ripple in the boost input inductor
Ibin = boost converter input current.
Considering a power rating of 50 W with boost input voltage of 5V, the boost input current, Ibin, is found as:

$$Ibin = power\ rating/\ Vbin = 50/\ 5 = 10A \qquad (3)$$

Also,

$$T = 1/F \qquad (4)$$

Where Vbin = input voltage applied to the boost converter

F = switching frequency
T = switching period

Substituting values from equation 3 and equation 4 in equation 2 and assuming the input current ripple, Δi, to be 1%, boost input inductor, L is found as 250Uh.

Similarly, the capacitor can be designed by the equation 5 given below:

$$C = power\ rating*T/\Delta Vdc*Vbout \qquad (5)$$

Where C = boost converter capacitor

Vbout = output voltage of the boost converter
ΔVdc = output voltage ripple in the boost convertes.

Substituting the value of switching period, power rating in equation 5 and assuming the required output voltage and its ripple to be 50 V and 1% respectively, the capacitor, c's value is 450uF.

C. Simulation Result

Simulation of both the conventional control system are the proposed control system which are carried out in MATLAB/SIMULINK using discrete time sampling of 1us. A DC source is said to be model of a diesel generator source. Boost switching uses frequency of 20 KHz. The inverter switches utilized a sinusoidal bipolar pulse-width modulation. A 60 Hz reference of sinusoidal wave is compared with 20 KHz of triangular carrier wave to generate the pulse-width modulation signals. Also modulation index for the single-phase is kept 0.8.

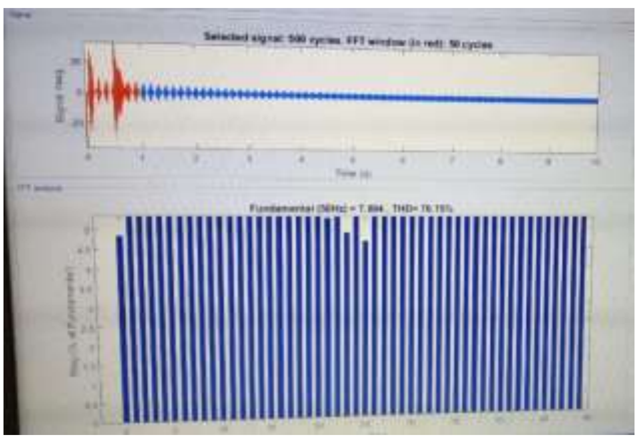

Figure 3 output without filter.

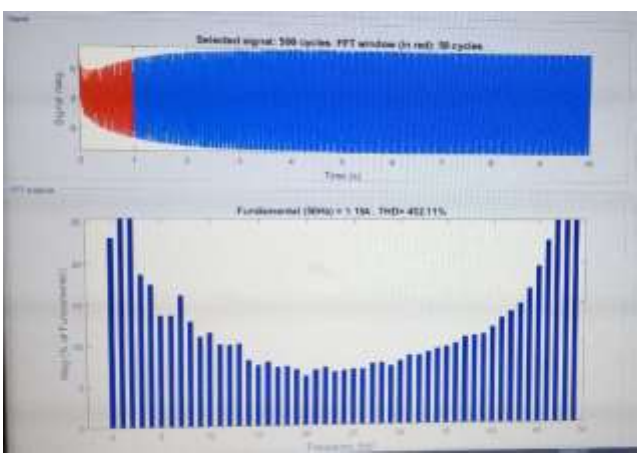

Figure 4 output with filter.

III. CONCLUSION

To solve the problem input with current rippling technique in single phase diesel genset power system, a loop current and control method is proposed for DC-DC boost converter stage. The proposed method may not require any additional circuitry, DC-DC converter control is designed in such a manner, that input ripple current is supplied by the DC-bus capacitor. The proposed analysis is simulated in MATLAB, and the simulation result side is free from ripple. Experimental result from a laboratory is presented and showing that the proposed approach reduces the harmonics of second current ripple from 65.28% to 2.88%.

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