Mitigation Of Harmonics In Power Network With Real Time Data Based On Etap

Guna, Hariharan, Mohan Kumar, V.J. Vijayalakshmi

Abstract: The emerging development of non - linear loads such as power electronic devices in industry is responsible for injecting harmonics into the electrical network. The static power converters like Variable Frequency Drives (VFD) are mostly used in industries for energy efficiency and process control of an induction motors. This situation cultivates deterioration of voltage and current waveform (i.e.) usually VFD drawn the current from the utility that's not same as applied sinusoidal voltage waveform. This paper aims to build a simulation model of gas cooling plant to evaluate characteristics of harmonics at different case studies with help of Electrical Transient and Analysis Program (ETAP). Generally, harmonic analyser in ETAP, studies the power network and is subjected to harmonic current injection and harmonic voltage at multiple frequencies and real time network is elucidated from voltage and current harmonic distortion at dominant harmonic frequencies individually. In this project, the harmonic pollution is analysed in ETAP and mitigation techniques are recommended which are that single tuned filters should be installed for worst case condition and simulation results of ETAP shows that harmonic voltage and current are well within the limit value as per IEEE 519 -2014 standard and provides theoretical lookout for the improvement of power quality in the power network.

Keywords: Non - Linear Loads, VFD, Harmonic Analyser, ETAP, IEEE 519 - 2014, Single Tuned Filter

1 . INTRODUCTION

A healthy assumption for most of the utilities is that voltage supplied to power network should be purely sinusoidal. When static power converters like Variable Frequency Drives(VFD) were introduced in all industries in the 1970's, handful of new problems become observable such as poor power factor at PCC, Error in the metering, poor voltage regulation on the ac side due to low power factor, unrestricted interference induced into telecommunication equipment, continuous neutral current in the neutral wire of the four-wire network. The use of non - linear loads change the sinusoidal nature of AC current, hence it results in the flow of harmonic currents in the AC power system. Even power factor improvement capacitors can cause high level of harmonic distortion when resonant occurs with non - linear load. As per IEEE 519 - 2014 standard, the limits set for steady - state condition and recommended for "worst case" condition. The recommended practice should be applied between utility and end user (i.e.) PCC where responsibility of utility ends / responsibility of customer starts. Generally, there is a requirement to acknowledge the characteristics of converter equipment with the introduction of the new filtering devices in the industrial sectors then need to increase the true power factor and alleviate the harmonics in the utilities can encounter new system problems. Probably, the most common passive filters used in industrial sectors are single tuned filters which creates low impedance path for the tuned frequency so that particular harmonic current will be diverted. If more filters are used for tuning dominating multiple frequencies, it will be important to remember that all of them will provide a certain amount of reactive power compensation to maintain desired power factor at PCC. In forthcoming chapters, modelling of the system for harmonic analysis, acceptable harmonic limits and the approach for the harmonic analysis are presented.

II. IMPACTS ON POWER NETWORK OVER VFD

VFD is a motor control device that controls the speed of AC induction motors. It can reduce the inrush current during of an induction motor. Mostly its used for energy efficiency and process control of a motor. VFD utilizes power electronic device to chop the sinusoidal waveform and causes non-linear waveform. This will affect the performance of the entire electrical network. A system with primarily nonlinear loads will display a more distorted waveform at the power source (i.e.) PCC. The below fig. 1 shows the schematic diagram of 6 pulse VFD which consists pair of thyristors in each three legs and its triggered and conduct until they are reverse biased.

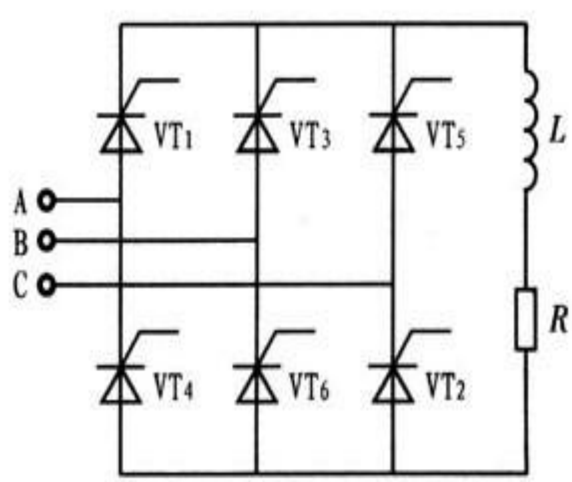

Fig.1 *Schematic Diagram of 6 pulse VFD*

An analysis will yield the following harmonic contents:

$$h = k*q \pm l \quad (1)$$

$$I_h = I_1/h \quad (2)$$

where,

h = harmonic order
k = Any integer (0,1,2,3….)
q = Pulse number of the circuit
I_h = Magnitude of the harmonic component
I_1 = Magnitude of the fundamental component

A. Harmonics order injected by six pulse converters

For a six-pulse converter, q = 6 and the line current contains harmonics of the order 5,7,11,13,17,19,2325,29,31,35,37…. These are referred to as characteristics of six pulse converter.

For a six-pulse converter, the following observations apply:

- No triplen harmonics are present.
- There are harmonics of order 6k ± 1 integer values of k.
- Harmonics of order 6k + 1 are positive sequence.
- Harmonics of order 6k – 1 are negative sequence.

B. Impacts on upstream network

The impact of harmonics on upstream electrical network has been classified on the basis of main impacts

- Mal-operation of relays

  Often increased harmonic effects followed by growth of non-linear load abruptly causes nuisance tripping of relay.
- Resonance

  Resonant condition occurs when reactive capacitance of capacitor bank matches inductive reactance of the system then it combines to produce series or parallel resonance and it increases drastically when harmonics exist.

C. Impacts on downstream network

The impacts of harmonics on downstream electrical network has been classified on the basis of main impacts

- Neutral Conductor Overloading

  The return current carrying conductor i.e. neutral wire contains zero sequence components (triplen harmonics) when significant amount of harmonic current flows through neutral wire of a transformer that increases the rms current.
- Overstress on Capacitor Banks

  The increase in operating voltage can cause overstress and shorten the life of capacitor bank.
- Pulsating Torques in Rotating Machines

  This may lead to issues on the shaft of rotating machines including bearing wear out, increased in vibration, mal-operation of mechanical fuses.

III. ETAP SOFTWARE

As power system become increasingly complex, it is a critical need to make available improved tools for analyzing the power system. In addition, it gives idea to the entry of industrial working professional into the power system with at least a basic understanding of an operation of the power system. ETAP is the most spacious analysis platform for the design, running system, existing system, operation, control, and optimization, generation, transmission, distribution, industrial, commercial power systems. ETAP provides a complete integrated software solution including load flow, short circuit, harmonic analysis, arc flash study, relay coordination, cable capacity, transient stability, optimal power flow, and more. Its entire functionality can be aid to fit the necessity of any industries from small to large power systems. Typical information for all equipment (Generator, Transformer, etc.…) is readily available which reduces the considerable time of the user. ETAP gives error report and highlight the critical and marginal alert to the user as detailed manner in report. In this paper, the 33kV system simulation model is built in ETAP 12.6.0. A 33kV bus is connected to utility grid via incoming feeder.

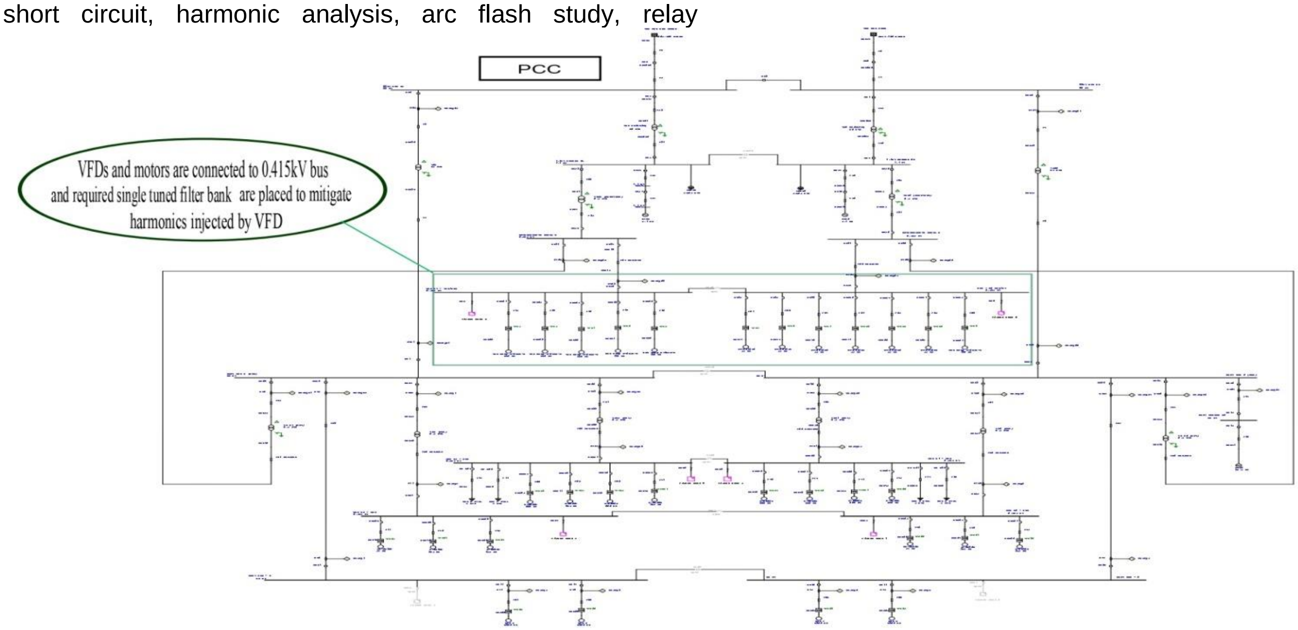

Fig 1. *Single Line Diagram of 33kV Bus Electrical Network*

IV. MODELLING SINGLE TUNED FILTER IN ETAP

Now-a-days the most essential harmonic filter in industrial sectors, the passive filter provides very low impedance at the tuned frequency, through which all current of that particular harmonic frequency will be diverted. Thus, passive filter design must take into account desired growth in harmonic current sources or load reconfiguration because otherwise it can be exposed to overloading, which rapidly develop into extreme overheating and thermal stress. The design of a passive filter needs a precise knowledge of the harmonic-producing sources(load) and of the power system. A simulation work is often needed to test its performance under dynamically varying load conditions or changes in the parameters of the network. Because passive filters provide reactive compensation to a degree dictated

by the voltampere size and voltage of the capacitor bank used, in fact they can be used for the double purpose of providing the filtering action and compensating power factor by providing required KVAR to the required level. If more than one filter is used — for example, combination of 5^{th} and 7^{th} and 11^{th} and 13^{th} branches — it will be important to note that all of them will provide a desired amount of reactive power compensation. As discussed, this filter is a series combination of an inductance and a capacitance. In reality, there will always be a series resistance, which is the internal resistance of the series reactor sometimes used as a means to avoid filter overheating and also used for damping the oscillations when harmonics occur. All harmonic currents whose frequency matches with that of the tuned filter will determine a low impedance path through the filter.

A. Filter Implemented at 0.415kV - MCC 11 and 12

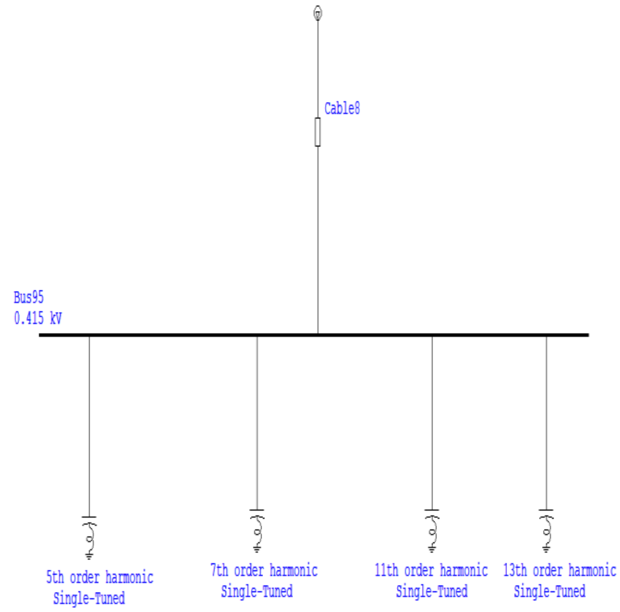

Fig. 2 *Filters tuned for 5^{th}, 7^{th}, 11^{th} and 13^{th} order*

B. Filter Implemented at 0.415kV - MCC 17 and 18

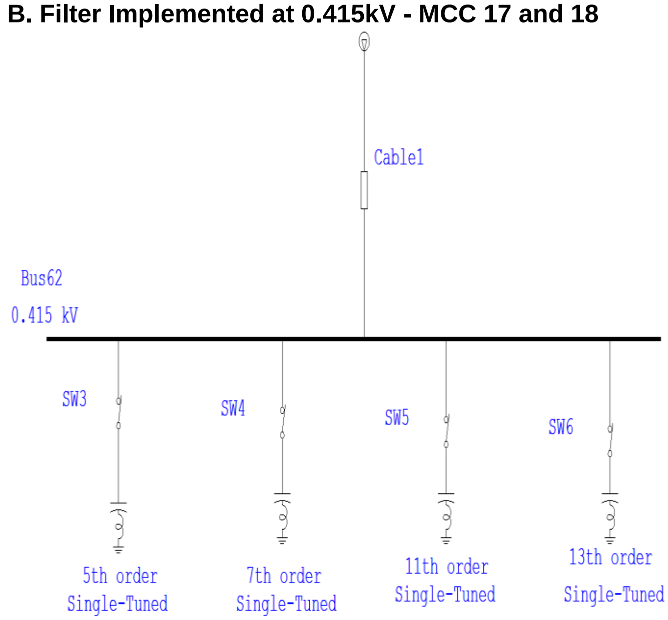

Fig. 3 *Filters tuned for 5^{th}, 7^{th}, 11^{th} and 13^{th} order*

Above filters are designed for worst case conditions so that it can mitigate harmonics for remaining cases

V. CASE STUDY FORMATION

%THD of voltage is lower under full generation scenario and this can increase when the system generation reduces to its lowest minimum.
Therefore, the harmonic study carried out here in has monitored the system performance under the following cases
Case 1: Entire Plant running in single grid source 33kV only.

Case 2: Entire Plant running in grid source 33kV and with GTG-1 and GTG-2 running.
Case 3: Entire Plant running in grid source 33kV and with GTG-1, GTG-2 and GTG-3 running.
HARMONIC ANALYSIS AND RESULTS

A. BEFORE ADDING FILTER,

Case 1, at PCC(33kV), VTHD = 19.05%
Case 2, at PCC(33kV), VTHD = 17.56%
Case 3, at PCC(33kV), VTHD = 11.68%

B. OBSERVATIONS AND RECOMMENDATIONS

The key observations and recommendations based on the Harmonic analysis study conducted are given below

- The Total Voltage Harmonic Distortion (VTHD%) at 33kV Busbar 1Land 33kV Busbar 1R which are the Point of Common Coupling are not within the permissible limits as per IEEE 519 standard.
- Since VTHD% at PCC are not within limit as per standard IEEE 519-2014, so filters are required and solutions are provided for "worst case condition" (i.e.) case 1 because THD% is higher in case 1.

C. AFTER ADDING FILTER

Case 1, at PCC(33kV), VTHD = 5.05%
Case 2, at PCC(33kV), VTHD = 4.92 %
Case 3, at PCC(33kV), VTHD = 4.01%

VI. HARMONIC ANALYSIS PLOTS

Below two figures shows voltage waveform for worst case condition (i.e.) case 1 before adding filter and after adding filter respectively.

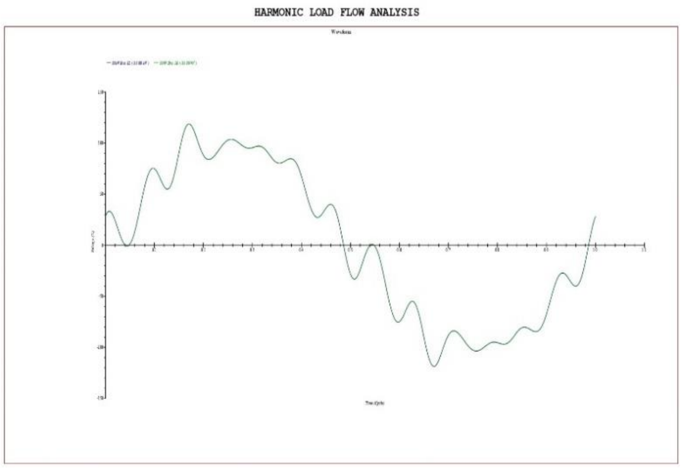

Fig. 4 *Voltage Waveform before adding filter*

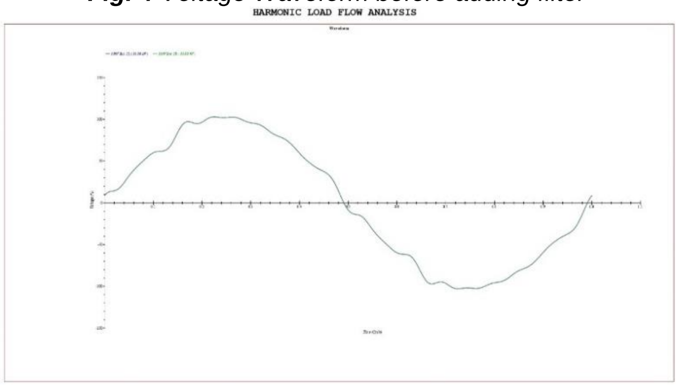

Fig. 5 *Voltage Waveform after adding filter*

VI CONCLUSION

The 33kV electrical network include variable frequency devices that can cause significant harmonic disruptions which affect the power quality provided to the users connected on the same network. The analysis of electrical power network that we proposed is focused to describe among which case that may affect power quality caused by connecting and disconnecting power grid and gas turbine generators. Power quality of supply has always been a special concern, because harmonic distortions are generating severe damages in power system. This is why specifically now-a-days modern industries put a predominant problem with power quality assurance. Integrating the filters for worst case condition i.e. case 1 in the 33kV proved significant improvement of the total harmonic distortion at PCC, reducing harmonic contents of the voltage waveforms and much better improvement in the voltage waveforms.

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