Power Quality Enhancement in Utility with Photovoltaic Renewable Energy Penetration Using Active Power Filter

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Abstract— In recent era, the efforts for harnessing electrical power from renewable sources increased significantly. Application of power electronics to harness electrical power from RES are posing serious power quality issues in grid. When power from such generation units integrated in utility grid it's power quality, stability, and reliability is getting compromised due to nature of generation and its dependency on various factors like irradiance, wind speed etc. The main objective of any electric power utility company shall be providing its end user reliable and quality of power at all time. Strict laws shall be made for power quality parameter compliances to avoid detrimental effects of power quality issues. This paper addresses control of current harmonics using shunt active power filter in utility grid generated by non-linear load. The solar PV energy penetration is used to mitigate harmonics distortion and bring it down to acceptable limits as per international standards.

Index Terms—Harmonics, Photovoltaic (PV), Power quality, Renewable Energy, Shunt Active power filter (APF), Total Current Harmonic Distortion (THD_i).

I. INTRODUCTION

Several characteristics of the current and voltage harmonic distribution of AC-DC hybrid microgrid using ETAP software are discussed [1]. Different latest control methods are summarized for a DG interfacing inverter providing harmonic compensation. More advanced virtual impedance based control systems needs be developed and explored in the coming time [2]. The analysis is presented for harmonic in grid connected solar PV system for variations in irradiance. Individual harmonic emissions and their interference associated with PV inverters integration in different scenarios are addressed [3]. Various types of inverters with different PWM techniques are discussed. From results it is found that SVPWM technique is good option for application of inverters with different industrial linear and non-linear loads [4]. Power quality problems, issues, and their effect in human life are discussed. Corrective measures are presented which can be used over power quality problems in different equipment. Existing industry practices and international standards for harmonic is also addressed in this paper [5].

It is good that we are explore alternate resources to be explored when conventional resources like petroleum, natural gas and coal reserves are about to be vanished approximately in next 49, 53 and 115 years respectively as per surveys conducted. The use of power electronics in power generation at RES plants and non-linear loads at end users are creating power quality problems which are damaging electrical equipment in power system, reducing efficiency and increasing losses at same time. Power quality issues also causes serious events like system instability and power outage in some cases. There are several power quality issues like interruptions, flicker, voltage sag/swells, overvoltage and undervoltage, harmonics, transients, noise. Among all of these harmonics and noise are the issues we have to focus more. The reason behind this is that all power quality issues are momentary in nature. They come and stays for short duration from micro-second to one min (maximum). Whereas harmonics are the component in system that once generated, it stays into the system unless and until we do not mitigate them.

II. HARMONICS AND IEEE GUIDELINES

Any non-fundamental component of frequency present in current and voltage waveforms called as harmonics. This non-fundamental component will be the multiple of fundamental component like 2f, 3f, 4f, 5f and so on. Even multiple of fundamental component – 100 Hz, 200Hz etc. called as even harmonics and odd multiple of fundamental component – 150Hz, 250Hz etc. called odd harmonics. A per IEEE STD 519 there are set values for current harmonics to be maintained in order to have compliances.

Individual Harmonic Order (Odd harmonics)						
I_{sc}/I_l	3<=h<11	11<=h<17	17<=h<23	23<=h<35	35<=h<50	TDD
< 20	4	2	1.5	0.6	0.3	5
20 < 50	7	3.5	2.5	1	0.5	8
50 < 100	10	4.5	4	1.5	0.4	12
100 < 1000	12	5.5	5	2	1	15
> 1000	15	7	6	2.5	1.4	20

In solar PV system the inverters use PWM technique which generated harmonics. The contribution of harmonic component depends upon the switching/duty cycle of IGBTs used in PWM. Sorter the duty cycle more will be the harmonic distortion. In wing energy the generated power supply will have different magnitude of power. The nature of current and voltage waveforms will also change as the frequency of generation will not be same at all-time due to changing speed of wind. The multi-cell converters are being used for compensating such scenarios. The inverters in BESS also one of the harmonics distortion contributors. At the end user point the non-linear loads draws short pulse current and this generates distorted waveforms in current.

There are major losses in motor, generator and transformer due to depending of eddy current and hysteresis losses son frequency. This cause insulation damage, pulsating torque, heating and reduces life of electrical equipment.

Hysteresis loss –

$P_h = K_h * B_m^{1.6} * f * v$

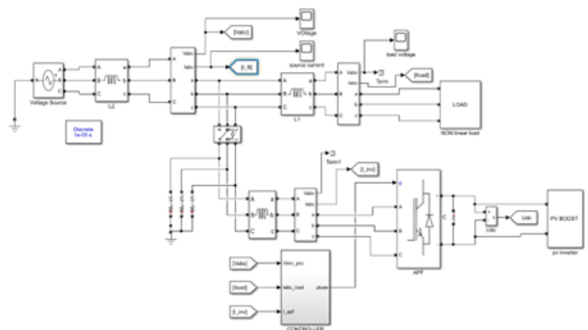
Eddy current loss –

$P_e = K_h * B_m^2 * f^2 * t^2$

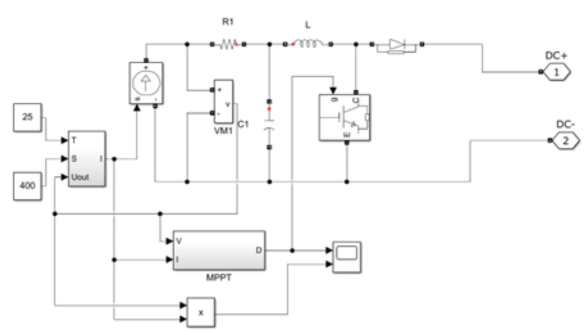
In transmission lines the third harmonic component causes a sharp increase in the zero-sequence current, and therefore increases the current value in the neutral conductor. Harmonics also causes interference with communication line, signaling, metering, control and protection system.

III. MATLAB SIMULATION

In order to study the harmonics generated in utility using the non-linear load at end user below power system is modelled in MATLAB and voltage and current harmonic component is analyzed at source end. The circuit breaker is having delay of 0.5 sec for closing and injecting the compensating component of current harmonics from solar PV system.

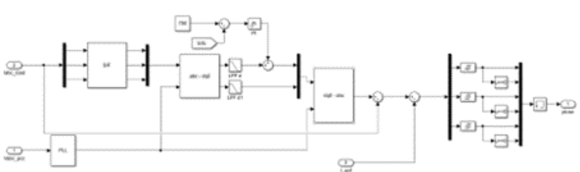


As the solar irradiance is changing continuously the MPPT system is modelled so as to get constant output from solar PV system for generating compensating power supply. An electronic DC to DC converter is modelled that optimizes the match between the solar PV array and the utility grid.

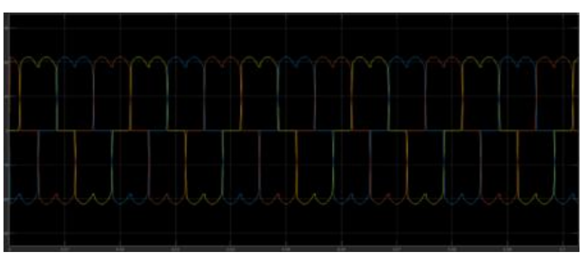


IV. SHUNT ACTIVE POWER FILTER (APF)

Shunt active power filters is very efficient when it comes to mitigate current harmonics and compensate reactive power for non-linear loads. The LC passive filter injects a high frequency current into the system and mitigates the harmonic components. Active power filters perform reactive power compensation and balances the imbalanced current. The PWM technique based voltage source inverters are preferred to model shunt active power filter. Active power filter generates the same amount of harmonic current as generated by the load side but in 180 deg phase shift. So when this harmonic is inserted into the transmission line at the point of coupling the load current harmonics are eliminated. Hysteresis current control technique is used for generation of six pulses signal to drive six IGBT switches of inverter of shunt APF. Hysteresis current controller generates signal pulses in such a way that inverter output current follows the reference current waveform.



Before getting APF into the operation the system has some major harmonics distortion as shown in below waveforms of source current due to non-linear loads and end user.



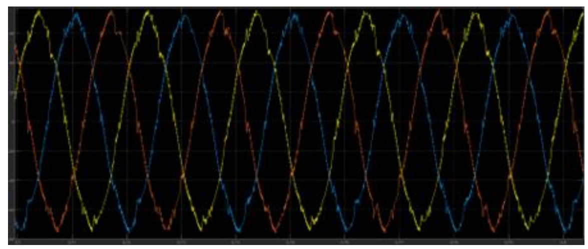
After switching the APF operation the harmonic current is injected into line and this mitigates the harmonics component of current. The Hysteresis current control generates the pulse using below references from source side to drive six IGBT switches of inverter of shunt APF.

$Va= Vd*cos\omega t - Vq*sin(\omega t)$

$Vb= Vd*cos(\omega t-2\pi/3) - Vq*sin(\omega t-2\pi/3)$

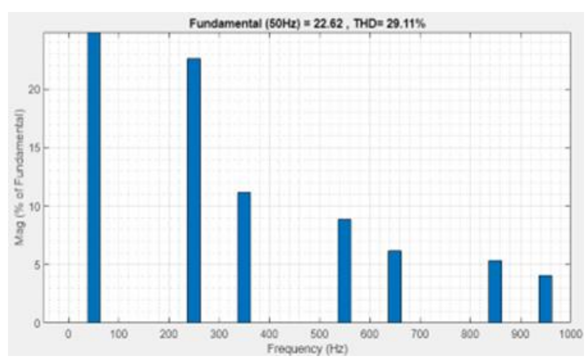
$Vc= Vd*cos(\omega t+2\pi/3) - Vq*sin(\omega t+2\pi/3)$

Voltage source inverters operates on PWM technique for generating the harmonic components of current in 180-degree phase shift. Below is the improved waveform of source current at source side.

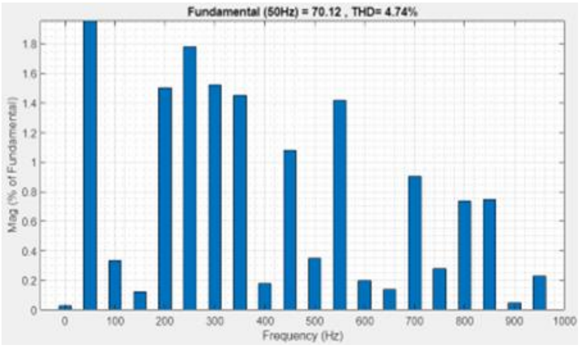


V. FAST FOURIER TRANSFORM (FFT)

FFT is nothing but method of analyzing and separating out the non-fundamental component of frequency from the overall distorted waveforms. From this the contribution of non-fundamental component of frequency is calculated and we can define the total current harmonic distortion. The FFT is calculated for one cycle duration before the APF in operation and after APF in operation.



From above figure we can see that total contribution of harmonic component t is about 29.11% when non-linear load is producing harmonics in utility grid.



Below is the result when APF is switched on after 0.5 sec and via circuit breaker the reactive power compensation is being performed by harmonic current injected by active power filter. The total harmonic distortion is coming down to 4.74% which is acceptable limit as per IEEE guidelines.

VI. RESULTS AND DISCUSSION

When APF is not in operation the THD for current is more and after 0.5 sec duration when APF comes into operation this distortion reduces significantly. While compensating the major harmonic components already present in utility grid APF injects some harmonics which are not initially present in system as long as the total harmonic distortion is below acceptable limits in IEEE it is considered to be safe.

Scenario	% Current harmonics
Without using Active Power Filter (APF)	29.11
With using Active Power Filter (APF)	4.74

CONCLUSION

The use of MPPT is demonstrated for providing stable power output from solar module to APF PWM. Hysteresis current control method in conjunction with voltage source inverter for pulse generation to drive IGBTs for generating the reactive power compensation harmonic current to be injected into utility grid for mitigating dominant harmonic component is discussed. Application of solar PV instead of utility power makes APF system safe and independent from problems that may reflect from utility system to APF system due to coupling.

REFERENCES

[1] Xiaran Chen and Guorong Zhang, Harmonic analysis of AC-DC Hybrid microgrid based on ETAP, IEEE 8th International Power Electronics and Motion Control Conference (2016): 978 1-5090-1210-7.

[2] Xiaodong Liang and Chowdhury Andalib-Bin-Karim, Harmonic Mitigation through Advanced Control Methods for Grid Connected Renewable Energy Sources, IEEE Transactions on Industry Applications (2017): 0093-9994.

[3] Annapoorna Chidurala, Tapan Saha and N. Mithulananthan, Harmonic Characterization of Grid Connected PV Systems & Validation with Field Measurements, Institute of Electrical and Electronics Engineers (2015): 978-1-4673-8040-9.

[4] R. Kameswara Rao, P. Srinivas, M.V. Suresh Kumar, Design and Analysis of Various Inverters Using Different PWM Techniques, International Journal of Engineering and Science (2014): 2319-1813.

[5] S. Khalid, Bharti Dwivedi, Power Quality Issues, Problems, Standards & Their Effects in Industry with Corrective Means, International Journal of Advances in Engineering & Technology (2011): 2231-1963.