Improvement of Power Quality in Grid Connected Photovoltaic and Wind Energy System

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Abstract:

Smart grids comprises of PV cell array, wind mills and power generators. Due to the nature of renewable sources such as sun and wind the output of such generators cannot be completely relied on. Furthermore, the fluctuating output sources results in total harmonic distortion in smart grid. Harmonics induce in the smart grid at different levels such as at transmission and distribution system and at load side. The harmonics in the grid eliminated with harmonic filters. In this paper, a harmonic filter design and connect at load side to analyse power quality. The smart grid, transmission & distribution system, harmonic filter and load design in simulink and the effect of harmonic filters are analysed.

Keywords: Smart grid, Harmonic filter, PV cell array.

I. INTRODUCTION

Smart grids has been developed due to adoption of renewable energy system that causes an increase in energy efficiency. For improving the power quality issues various control strategies is implemented . Performance of electrical equipment is affected due to disruption of distribution system which ultimately depend on the power quality efficiency. It is important that problems to be mitigated for proper function of Equipment. The normal operation of equipment is deviated due to power quality issues that causes disturbances .Major issue is degradation of power Quality parameter in the power distribution. It has to be reduced with in the acceptable limit. So the disturbance due to power quality as to identified and reduced to be within acceptable limit..In this paper RLC based harmonic filter is implement in Simulink design to mitigate harmonic distortion caused by HPW in a smart grid environment.

II. LITERATURE REVIEW

The S transform apply to monitor power quality in lines. The spectral characteristics of wavelet transform apply to evaluate spectral analysis. The phase values vary with absolute reference points for phase correction, maintaining stationary amplitude peaks. The frequency response of S-transform [1]. The current and voltage waveforms acquire via digital fault recorders. The large data set collect and apply for post processing. An automatic event detection system produced flag at fault instances. A prediction based filters and rule based system produces localization and detection [2]. The voltage and current deflection cause power quality degradation. The power quality affect by sag, swell and harmonics. The power quality disturbances analyse with Fuzzy logic, Bayseian classifier, Artificial neural network and pattern recognition techniques [3]. The voltage and current disturbance detect in real time by IIR notch filter. The Phase locked loop controls the notch filter for frequency estimation. The notch filter evaluates every sample output of frequency estimator. Following the filter the fundamental and error component extract and apply to Bayesian detector for power quality analysis [4]. A study conduct on photovoltaic power system to determine the effect of PV- inverter interfaced system on electric power quality. The harmonic distortion performs with BC Hydro harmonic current for IEEE 519-1992 standard comparison [5]. The study analyses the effect of fluorescent lamp on power quality. The harmonic current and total harmonic distortion by a group of lamp helps determine diversity factor [6]. In this paper modelling and simulation of hybrid wind and photo voltaic with grid connected load uses shunt passive filter for reactive power and harmonics compensation. In this paper RLC based harmonic filter is implemented in Simulink design to mitigate harmonic distortion caused by HPW in a smart grid environment

III POWER QUALITY IMPROVEMENT IN GRID CONNECTED HYBRID SYSTEM

Smart grids comprises of different renewable voltage sources such as Photovoltaic cell voltage generators and Wind turbine generators. The output of the generators relies on sun light and wind respectively. The sun light and wind energy are not constantly available throughout the entire day. The sources vary from time to time depending on natural phenomenon

Hence, the output from these voltage sources cause difference in voltage output. The fluctuating voltage output produces total harmonic distortions. The total harmonic distortion (THD) has varying effects on different types of load. For an induction motor the THD increases the winding temperature and causes degradation. Hence, RLC based harmonic filters apply across load lines to reduce current harmonic level. A generalised smart grid with photovoltaic cell and wind turbine generator is shown in figure 1. The voltage produced by renewable resources transfer via long distance transmission line. The resistance in transmission line reduces the current level. . Hence a step transformer place to improve the incoming voltage. The harmonics level is high at current level, affecting the smooth operation of loads. The harmonics occur due to loss in voltage during transmission. The losses include resistive losses, heat due to resistance and electromagnetic field. Considering a single point transmission line system from source to end consumer the resistance in transmission line give by

$R = \dot{\rho}\frac{L}{a}$ (1)

Where, ρ is the conductive element resistivity. The inductance in transmission line generate due to current flowing in the conductor. The current flow in conductor produce magnetic field around the conductor. The magnetic field induces electromagnetic field which affects the flow of current in line. The inductance in transmission line is give by

$\mathrm{L} = 2 * 10 - 7 \ln(\mathrm{D}/\mathrm{r1}')$(2)

Where D represents distance between the conductors

$\mathrm{r1}' = \mathrm{r1} * \mathrm{e} - (1/4) = 0.7788\,\mathrm{r1}$ (3)

r1 is the conductor radius

$\mathrm{L}' = 2 * 10 - 7 \ln(\mathrm{D}/\mathrm{r2}')$ (4)

R2 represents conductor radius r2.

$\mathrm{Lt} = 4 * 10 - 7 \ln[\mathrm{D} / \sqrt{}(\mathrm{r1}'.\mathrm{r2}')]$ (5)

The inductance level Lt is given by

$\mathrm{Lt} = \mathrm{L} + \mathrm{L}'$ (6)

The total inductance in the transmission line is given by

$\mathrm{Lt} = 4 * 10 - 7 \ln[\mathrm{D} / \sqrt{}(\mathrm{r1}'.\mathrm{r2}')]$ (7)

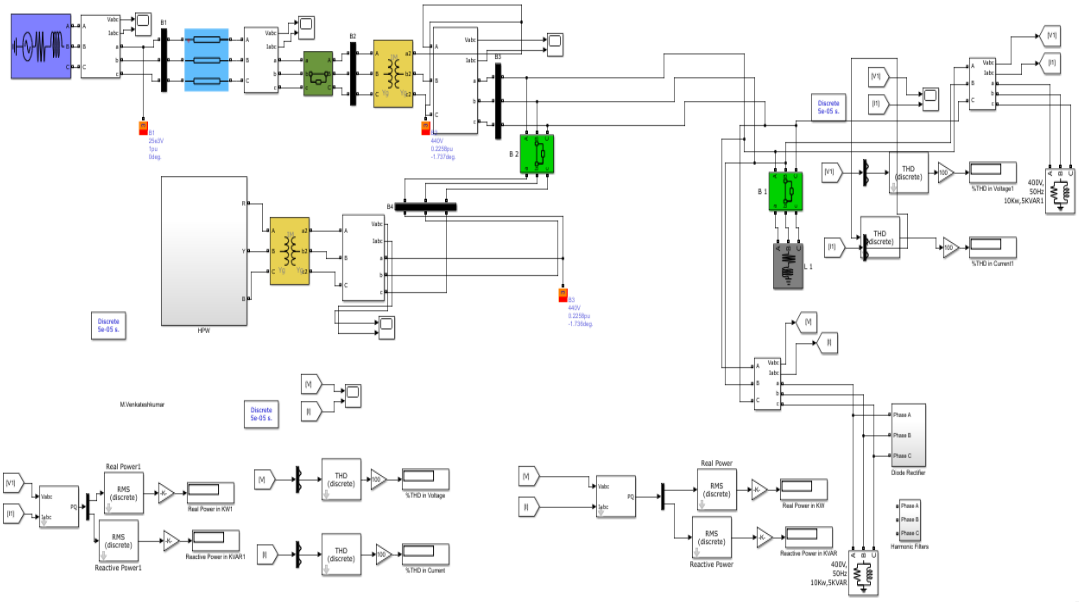

Figure 1: Generalised Smart grid System Simulink design

The line from transmission line pass through step up transformer to make for losses endured during transmission. The photovoltaic cell output applies to the step up transformer output. The simulink design of PV array is

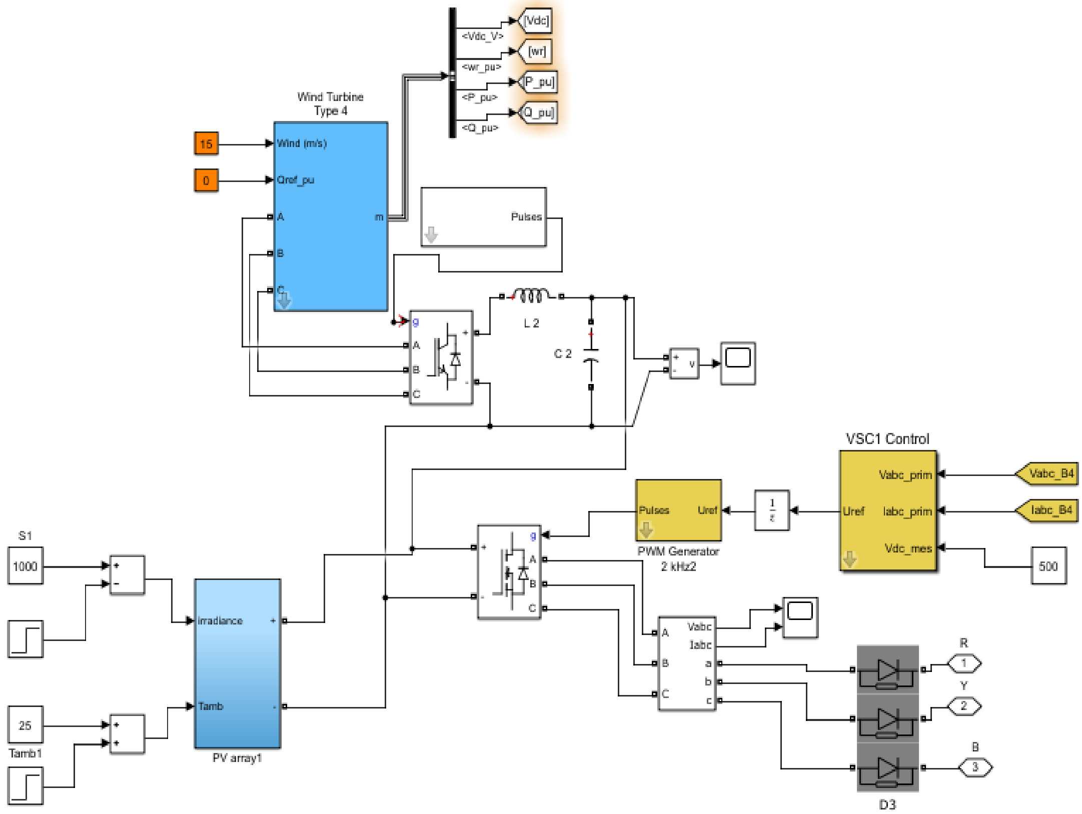

Figure 2: Photo voltaic array detailed simulink design

shown in figure 2. The combination of harmonic filters and their equivalent simulink design is shown in figure 3. The RLC combination of filters reduces the current harmonics in the end user side.

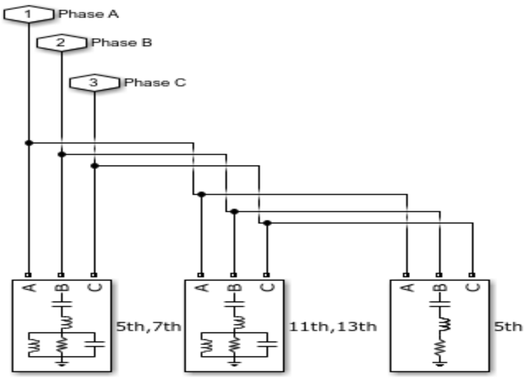

Figure 3: Harmonic filter simulink design

The filter design to suppress different harmonics namely 5, 7, 11 and 13 as shown in figure 3. The filter design to based on quantities such as quality factor, current order blocking and capacitive reactive power. The design equation for harmonic filter gives by

$$Z(W) = \left(\frac{1}{R} + \frac{1}{jWL - j(WC)^{-1}}\right)^{-1} + \frac{1}{jWC_1}$$

$$Z(W) = \frac{R\times(W^2LC-1)^2 + jR^2WC\times(W^2LC-1)}{(RWC)^2+(W^2LC-1)^2} - j\frac{1}{W\times C_1}$$

Where,
Z=impedance
R=Resistance
L=Inductance
C=Capacitance

IV RESULTS & DISCUSSION

The smart gird incur current harmonic at different stages of transmission. The detailed analysis of the transmission line output and harmonics are explained below. The RLC

source output is shown in figure 4 for voltage and current (3-Phases). From figure 4 the voltage and current have minimal fluctuations.

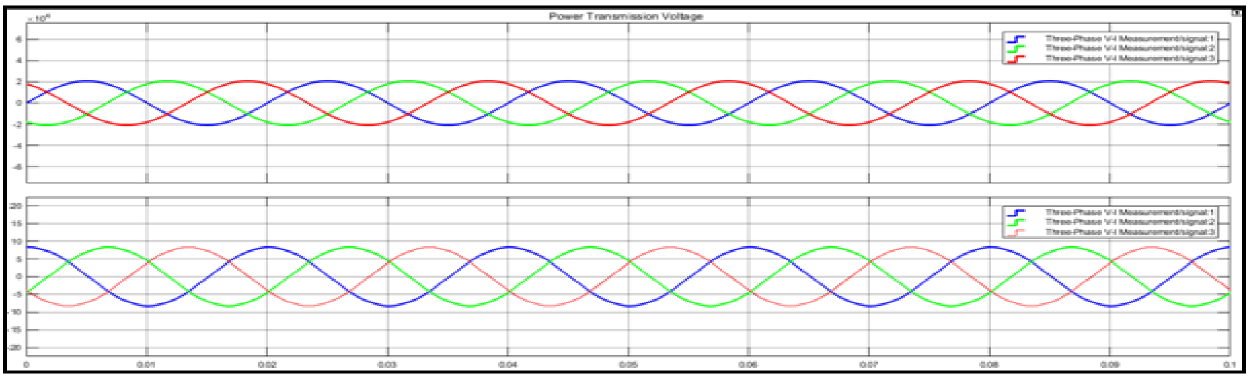

Figure 4: RLC source output

The output during transmission line is shown in figure 5. The current loss in transmission line was from 10 in figure 4 to 0.2 (amps) in figure 5. The loss occur due to resistance, heating and electromagnetic flux around transmissionlines.

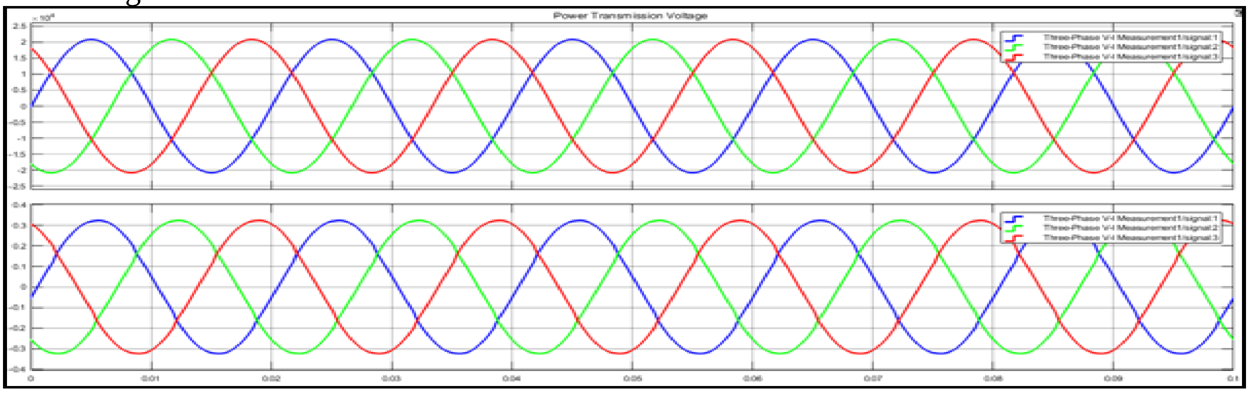

Figure 5: Transmission line

The transmission line output step up by step up transformer to improve current. The output current increases above 50 amp by step up transformer as shown in figure 6.

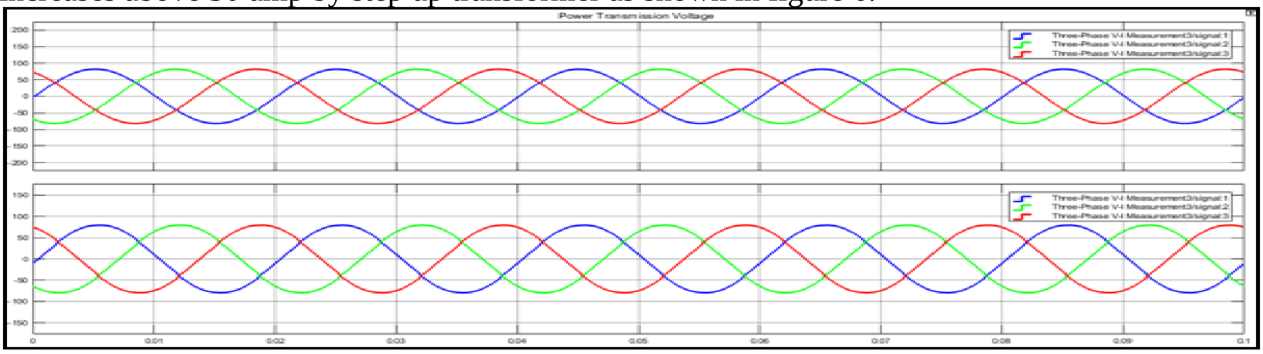

Figure 6: Step up transformer

The output of renewable resource PV cell array is shown in figure 7. In Figure 7 the output current is low compared to current output in figure 4.

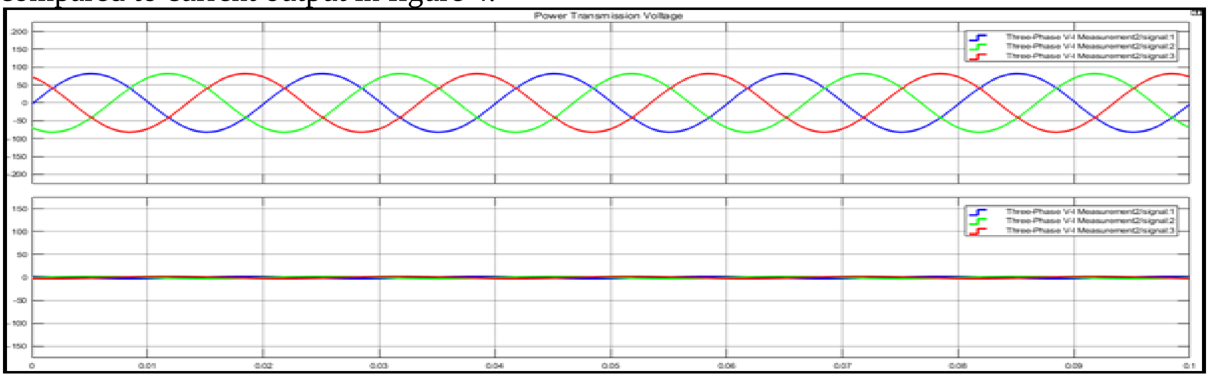

Figure 7: Solar cell output

The voltage and current at the load side without harmonic filter is shown in figure 8. The current harmonics are high, resulting in reduced current from the RLC source output. The current output from RLC source is 4 as in figure 4 which reduces considerably to 0 in figure 8.

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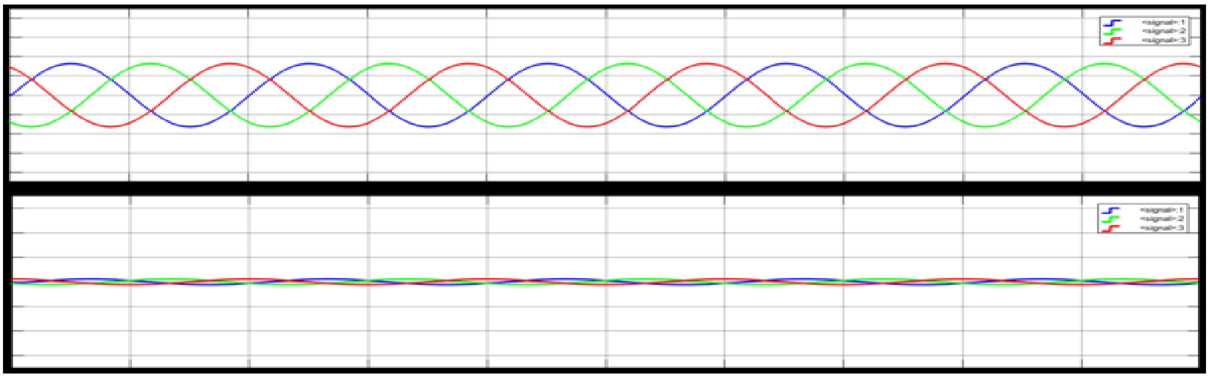

Figure 8: Three phase Voltage current measurement for load without harmonic filter

The harmonic filter apply at load side to improve current. With the designed harmonic filters the current improve considerably. Comparing the current level signatures from 8 & 9 the harmonic filter reduces current harmonics.

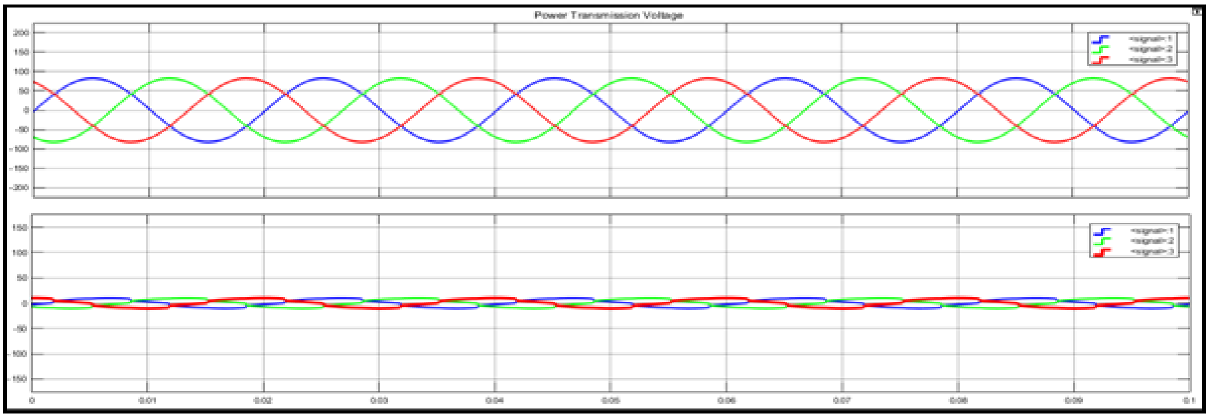

Figure 9: Three phase Voltage current measurement for load with harmonic filter

The total harmonic distortion for current level are 13.62% at load side without harmonic filter. With the harmonic filter connected to the load side the current total harmonic distortion reduces t 7.261% improving current level as shown in figure 10 & 11.

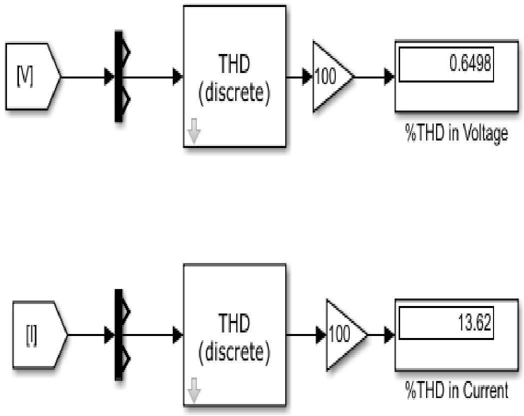

Figure 10: Load without harmonic filter

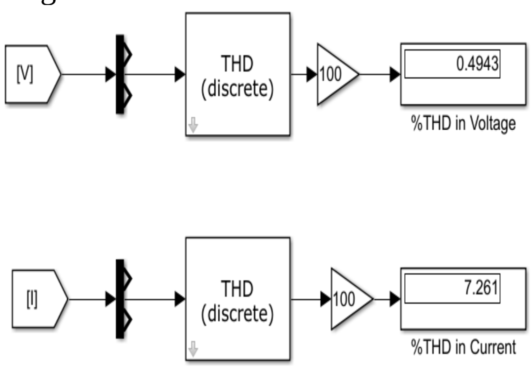

Figure 11: Load with Harmonic filter

V Conclusion:

A RLC based harmonic filter implement in Simulink design to mitigate harmonic distortion caused by PV cell array in a smart grid environment is proposed. The harmonic filters design with resistor, capacitor and inductor components. The proposed harmonic filter and smart grid design in Simulink and simulate to analyse harmonic filter effectiveness. The harmonic filter reduces 5,7,11 & 13 odd level harmonics. The theoretical design of harmonic filter reduces odd harmonic levels from 13.62% to 7.26%. The current harmonic levels mitigate and improve with proposed RLC harmonic filter. The filter further improves load operation level and lifetime.

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