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Control System for Voltage Source Converter (STATCOM) Scheme for Power Quality Improvement for Grid-Interactive Solar Photovoltaic Arrangement

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Abstract— ***Maintaining the power quality with emerging power requirements with more electronically powered load connected to a power system is a challenge, specifically at distribution level, where a significant disturbance in power supply system occurs due to the reactive power component. Solar PV(SPV) SYSTEM is a smallest, cheapest and easiest technology available now as power source is concern at distribution power network level. This emerging technology combines with Voltage Source Convertor based STATCOM scheme can minimize the power quality issues in distribution network. By proposing the better control operations of VSC based STATCOM scheme, required reactive and active power can inject into power network to reduce the power quality problems. By using MATLAB/Simulink analysis of such schemes for control and it out come can be check and compare for power quality factors. A better control method can be explore based on study and analysis of proposed methods till date and further research on the possible methods for the same can be investigate, compare and suggest for grid interactive Voltage Source Control (VSC).***

Index Terms— ***POWER QUALITY, SPV, STATCOM, VSC.***

I. INTRODUCTION

Idea of renewable energy sources come into picture to source Green Energy and to reduce undesired greenhouse gases. As a clean energy and approachable easiest way of solar PV based energy module accepted worldwide and lots of research going on further to get more efficient PV modules. At the same integration of this source at distribution level gives an opportunity to take an advantage of energy to mitigate the emerging power quality issues. Under this topic of control of VSC based STATCOM scheme by means of injecting the reactive and active power as per requirement of network studied and analyzed with the help of recent researches on the control strategies of VSC. Some of control approaches such as least mean square technique, leaky based control. Second order generalized integrator and an adaptive control scheme etc. are presented in literatures. Here by taking reference of an adaptive control scheme MATLAB/Simulation program prepared for study and analyze the results. An adaptive control scheme for linear and non-linear loads analyze and studied. Control of Voltage Source Converter (VSC) based SATACOM scheme for Grid connected Solar PV system is a key factor to manage the Power Quality in Grid. A better control scheme will provide a sustainability to a Power system by compensating reactive power demand, with balancing active power and mitigate harmonic current in system. At distribution level Roof top Solar PV SYSTEM available now as a power source. At distribution level a small source units of Solar power will contribute a lot to minimize the power quality issues in distribution network. An Adaptive Control Scheme, An Adaptive Back Propagation control technique, Enhanced Phase locked loop control, Fuzzy Logic & PI controller are example of some recent experiments are presented in papers / literature to present the possibilities for improvement of Power Quality with the help of Grid Connected Solar Photovoltaic System and further research and analysis on the VSC control schemes will benefit to Power System.

II. PROJECT SCOPE

Power Quality is a compatibility problem between source and load which leads to an unbalance and unreliable Electrical Power Network.

The most common types of Power Quality Issues:

Voltage Sag & Swell
Interruptions
Voltage spike
Harmonic distortion
Voltage fluctuation & Unbalance
Noise

STATCOM is a Prompt response device capable to provide or absorb the reactive current and thereby enable regulating the voltage level at the point of connection to a power grid and the possibility of feeding the grid generates with the maximum available reactive Power even at Distribution voltage levels and this gives opportunity to work on Voltage Source Converter Control Scheme for Improvement of Power Quality In Grid-Interactive Solar PV System.

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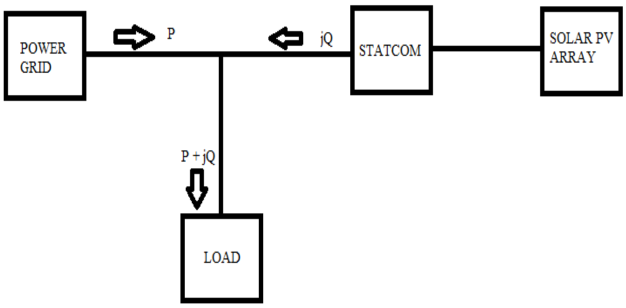

Fig 1: Basic Working Scheme proposed

III. PROBLEM STATEMENT

In view of availability of Solar Renewable Energy and proposed increase in the capacity and increasing in Power Quality Issues with Power Grid as it becoming more complexed and interactive with various types of Sources and Connected Load as well. It is the requirement to utilize such renewable sources connected to grid with such FACTS Devices STATCOM to control and mitigate the Power Quality Issues occurred through Reactive Power Component. Transformer Faults, Line faults, Connection of Heavy Load like Starting of big Capacity Motors, Isolator / Breaker operations also creates an unbalance in Voltages which cause tripping to other connected relays and loads and finally it leads to an unbalance of load in 3 Phase System. Lightning, insulator flashover, operation of protecting devices, Human errors, operations of power factor improvement devices, use of electronics switches / starters are some of examples which may cause for shorter or longer interruptions but in any case, it would impact on power quality in terms of Unbalance in voltages, Increase in reactive power requirement, harmonic distortions etc. At distribution level such problem become more complexed and frequent. Solar Renewable Energy Source at distribution level will provide a significant solution to this at distribution level. Various algorithms-based control systems have been proposed and suggested in various literatures to resolve the problems associated with the Power quality. The paper in this report studied and analyzed with MATLAB Simulation also focused on controlling of Voltage and harmonic Distortions. As the use of electronic devices increased and most of the microprocessor-based control devices are in use now a days, an issue of malfunctioning in input signals or say a mis-information due to said power quality issues may cause the sudden disconnect of load from a healthy system and impact of it convert in unbalance. As we have such renewable and controllable source of power with help of Inverters, we can mitigate or limit such problems at distribution level and limit the further impact to primary distribution and above higher voltage power transmission levels. Changes in Voltage, Current and Frequency values are the key terms which lead to any Power Issues. The change in one component will create disturbance in other component values, so it is necessary to control these values as good as possible at every level in Power System. A well-known example is use of Power Factor Improvement Capacitor banks to limit reactive power requirements at Load only. Similarly other FACT Devices in High Voltage Electrical Circuits mitigate such issues. Similarly in Distribution network Solar Energy can provide such solutions as well.

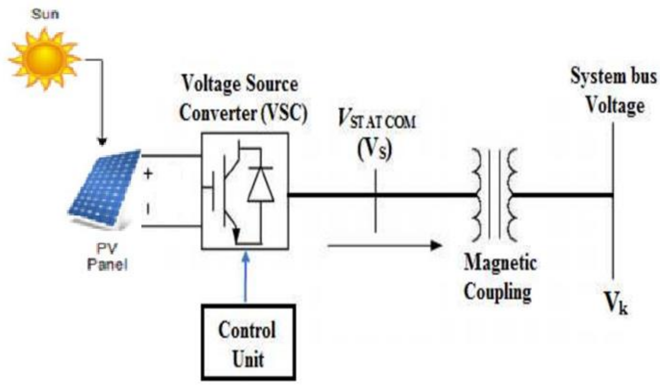

Fig 2: Representation of the Grid Connected Solar PV System

IV. MATHEMATICAL REPRESENTATION

Mathematical Representation for extraction of reference values from DC Bus:

Vspv (r) represent updated or real time Voltage value.
Vspv (r-1) represents a and past samples Voltage value.

ΔVspv (r) = Vspv (r) - Vspv (r-1)

ΔVspv (r) is the deviation in voltage values in real time.

Similarly Current Reference can be extract as follows:

ΔI spv (r) = I spv (r)-I spv (r-1)

Ratio of Current Deviation ΔI pv and Voltage Deviation Δ Vpv will compare with the Real time Current and Voltage Value to get the Reference Voltage input from the INC Based MPPT.

If ΔI spv / ΔVspv > (-) ΔI spv / ΔVspv

Then DC Link Reference Voltage will be

Vdc* (r)= Vdc* dc (r-1) + ΔVdc (r)

If ΔI spv / ΔVspv = (-) ΔI spv / ΔVspv

Then DC Link Reference Voltage will be
Vdc* (r)= Vdc* (r-1)

And if ΔI spv / ΔVspv < (-) ΔI spv / ΔVspv

Then DC Link Reference Voltage will be

Vdc* (r)= Vdc* (r-1) - ΔVdc (r)

Where Vdc*(r) is Updated Sample and Vdc*(r-1) is a past samples from the reference DC link voltage.

The SPV feed-forward term, load currents and point of

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interconnection voltages are utilized for generation of grid reference currents. The feed-forward loop from PV array is estimated as

$$Ispvf = (2/3) \times Pspv / Vt$$

Where Vt is the magnitude at point of interconnection for Phase Voltages.

At point of interconnection the voltage between phase a, b & c measured and value of Vt estimated as follow

$$Vt = \sqrt{\{2/3*(Vsa2 + Vsb2 + Vsc2)\}}$$

Quadrature unit vectors, evaluate from the phase unit vectors

Where unit vectors per Phase will be

$$Wpa = Vsa / Vt ,$$
$$Wpb = Vsb / Vt,$$
$$Wpc = Vsc / Vt.$$

Quadrature unit Vector evaluate with following equations.

$$Wqa = (Wpc-Wpb)/ \sqrt{3},$$
$$Wqb = (Wpa-Wpc)/ \sqrt{3},$$
$$Wqc = (Wpb-Wpa)/ \sqrt{3},$$

For the understanding of adaptive control arrangement, magnitude & frequency of the fundamental component of phase currents (Ifla) must be expressed correctly.

Equation: Removal of fundamental Component from the Load Current for Control Equation is express from below equation

$$I_{fla} = 1/S* \left[\{G_1(I_{la} - I_{fla}) - \frac{I_{fla} \times \omega_n}{S\{1 - (I_{fla} \times I_{l3} \times e \times G_2)/S^2\}} \right] \times \left[\frac{I_{l3} \times e \times G_2 + \omega_n}{S} \right]$$

Where Controller Gains G1 and G2 are Constant values to control the performance of control arrangement Proposed in steady and dynamic state condition.

e is a difference between phase current Ila and Fundamental Component of phase current Ifla.

$$e = (Ila - Ifla)$$

"S" represents the integration in closed loop control function equation.

By utilizing sample and hold logic, Quadrature unit vector values (Wqa, Wqb, Wqc) and absolute fundamental real power current components of all 3 phases is assessed.

As these mathematical equations do not have any trigonometric function or voltage control oscillator (VCO) in its formation. Therefore, it is fast as compared to other schemes. The fundamental component extraction and active power component estimation of proposed control scheme Simulation Prepared and checked for the given results.

V. CIRCUIT DIAGRAM OF SIMULATION FOR AN ADAPTIVE CONTROL SCHEME PREPARED FOR STUDY & ANALYSIS.

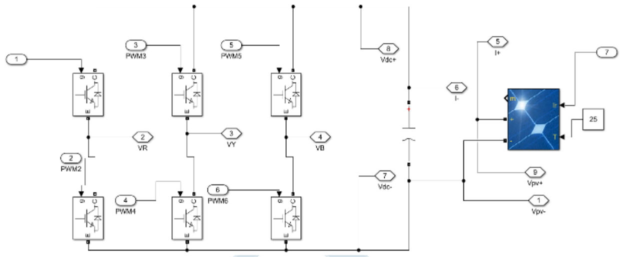

Fig 3: Inverter Circuit with Solar PV Panel

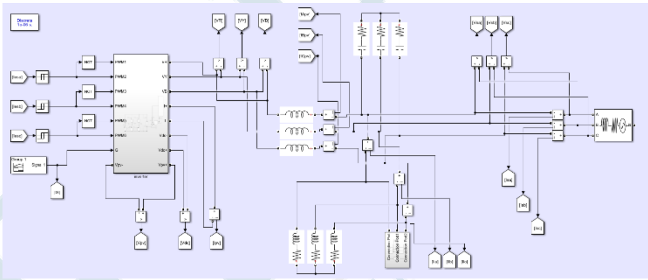

Fig 4: System Layout

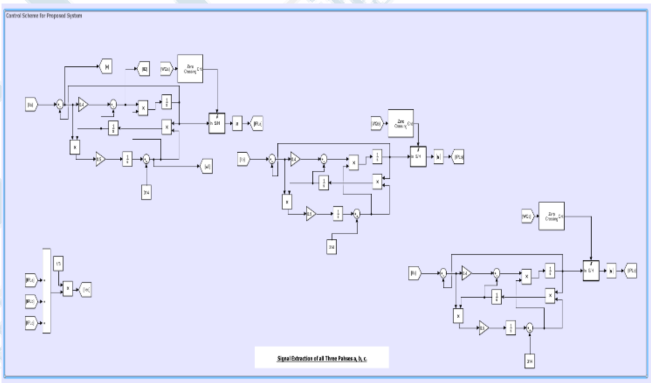

Fig 5: Control Scheme for Proposed Adaptive Control Scheme for Signal Extraction from all 3 Phases

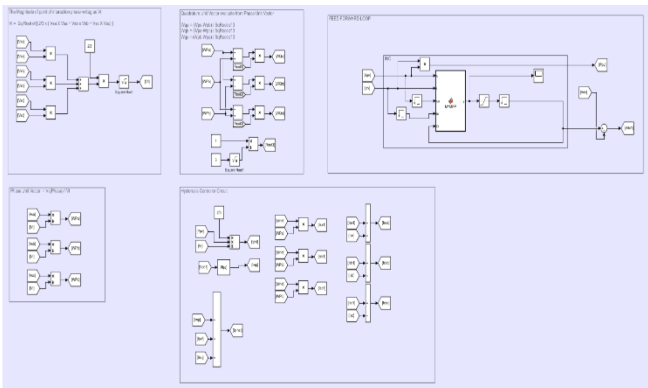

Fig 6: Feed Forward Loop and Other respective Voltage and Current Input Circuits.

Note: Paper Referred[1] for the Simulation Experiment: An Adaptive Control Scheme of SPV System Integrated to AC Distribution System

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VI. EXPERIMENTAL DATA REFERRED FOR SIMULATION AS PER PAPER ONLY.

Following are the Data Referred:
PV Module:

Voc = 32.9 V. (at 1000 W/m2), Isc = 8.3 A. (at 1000 W/m2)

SPV Module:

Ppv = 5 KW, DC Bus Capacitor = 2200 Micro Farad

Distribution Voltage:

Vs = 415 V, Supply Frequency: f = 50 Hz

PV Module inputs in Simulation:

Vmp = 27.8 V
Imp = 7.5 A
Ns = 54
ns = 21
np = 2
Lb = 2.36 mH
Vdc = 690 V
L = 5.5 mH
PI Controller: Kpd=1.5, Kid=1.8
Adaptive Control Gains: G1==0.4, G2=0.5
Grid Impedance: Ls = 3 mH, Rs = 0.06 Ohms
Linear Loads: 60 Ohms, 95 mH,
None Linear Load:
Diode Bridge Rectifiers with 200 mH, 60 Ohms
Ripple Filter:
Cr = 5 micro farad, Rf = 10 Ohms, ω = 314 rad/s

VII. RESULTS FROM PAPER REFERRED & SIMULATION RESULTS FOR REVIEW.

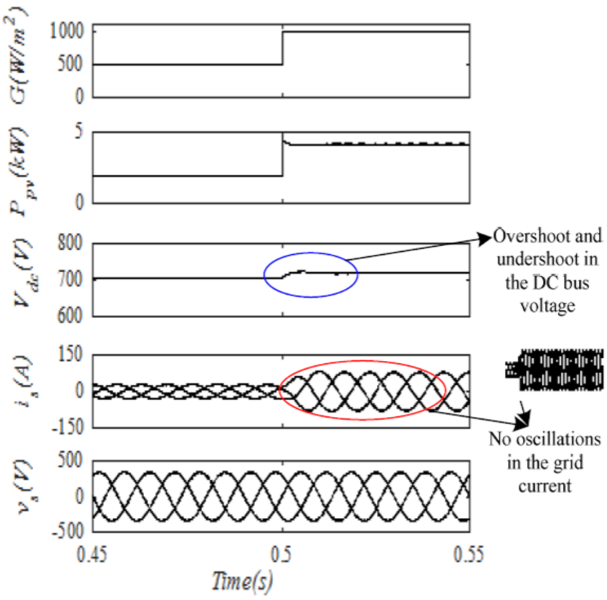

Fig 7: Performance observed in paper referred[1] of Adaptive Control method with PV feed forward loop for reference.

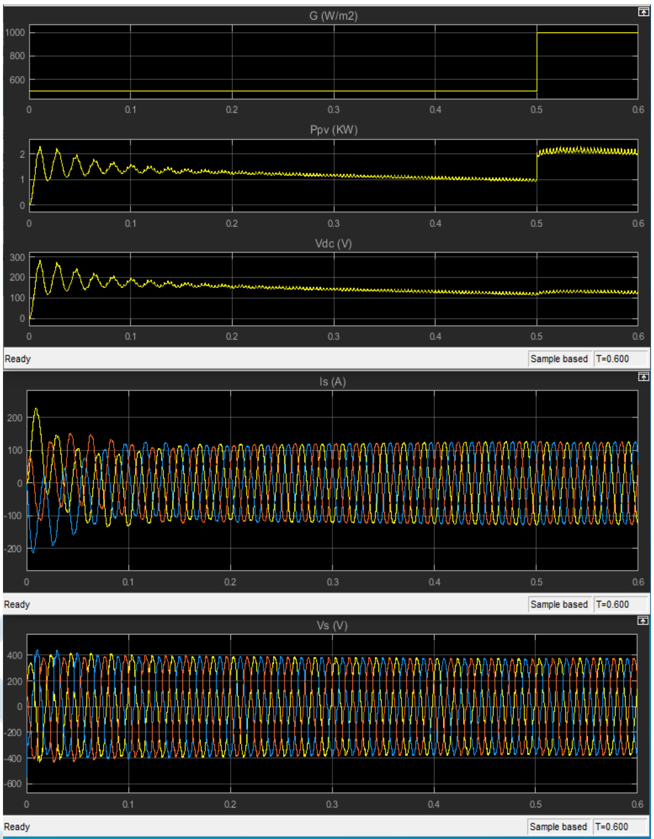

Fig 8: Performance of proposed control approach with PV feed forward loop from Simulation Prepared

VIII. OBSERVATION FROM THE VARIOUS LITERATURES AND THE EXPERIMENT ON SIMULATION PERFORMED FOR ADAPTIVE CONTROL SCHEME OF SPV:

For further modification to utilize the Solar PV System to balance the grid current back propagation control[2], modified MPPT method for reactive compensation for grid connected PV System[3], presented in literatures can be refer for update and modify the control scheme. Similarly, other reference from different control scheme used, like SPV grid connected system based on STATCOM[4,] Voltage and Current Quality Improvement by SPV fed Impedance Source Inverter with DVR[5] control algorithms can be refer.

Following control operations from Voltage Source Converter also can be achieved.

1. Reactive Compensation:

SPV Grid Connected VSC based STATCOM will send active current and reactive current by controlling Inverter Voltage Output in reference to Grid Voltage by means of managing the phase difference between the said voltages and magnitude of inverter Voltage.

2. Harmonic Distortion:

The Control Methodes presented in various literature presented that in all opertaing states the Total Harmonic

Distortion (THD) of grid current is found satisfactory and with in the limit as per IEEE recommendations (IEEE Std 519). This is to examine with trial and error method by changing parameters of control algorithm PI Controller and Gain value constants to verify the ressponses and to identify the particular function in control algorithm is affecting the THD response.

3. Voltage Sag / Swell:

Control is to be monitor the amount of missing Voltage component during Sag / Swell interption in system and allow to inject the same to balance the system voltage.

IX. CONCLUSION

Simulation Prepared for the experiment validated the given results and performance of the Adaptive Control Scheme with the solar PV system. For a Supply of a better Power quality the approach can be implemented at distribution Level where the System Power Quality issues can be managed and control easily. Implantation of the scheme at distribution level, higher Primary Distribution and Transmission Network will get benefited from the same.

X. ACKNOWLEDGMENT

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[5] Voltage and Current Quality Improvement by Solar Photovoltaic fed ZSI-DVR (Miska Prasad & A. K. Akella, NIT, Hamshedpur.