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Analysis of Power Quality Problems in Solar Power Distribution System

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ABSTRACT

Photovoltaic systems have been increasingly used in the generation of electrical energy because of the cost of energy produced from fossil fuels is rising day to-day and there by photovoltaic energy becomes a promising alternative source for fossil fuels. Power quality is the major problem that occurs between grid to end user transmission lines. DSTATCOM is the one of the power quality compensating device which will rectifies the power quality problems such as voltage sag and swell which occurs in high voltage power transmission lines. The work was proceed by using Simulink / MATLAB software and to solve the voltage sag and swell and the model was developed. By using this DSTATCOM device in the MATLAB SIMULINK model the problem occurred has been rectified and the graph has plotted. It is high economically effective in transmission lines and more safe to end-user equipments.

Keywords – Distribution networks, Inverter, Power Quality, PV Systems, STATCOM, Voltage Sag & Swell.

I. INTRODUCTION

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and increasing cost. It's necessary to look towards renewable sources as a future energy solution. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth.

Photovoltaic technology provides an attractive method of power generation and meets the criteria of clean energy and sustainability. Advanced research is still in progress to increase the efficiency of photovoltaic cells and optimize the production of energy through minimization of power losses and better utilization of incident solar irradiance. The efficiency and proper operation of photovoltaic systems depends on a number of factors. Environmental conditions as well as system design constitute the most important factors in the operation of the PV systems and these can have a significant impact on the efficiency and power quality response of the whole system. The variable power flow due to the fluctuation of solar irradiance, temperature and choice of power semiconductor devices are some of the parameters that affect the power quality of photovoltaic systems. Good power quality translates into obtaining a sinusoidal voltage and current output from a photovoltaic system in order to avoid voltage sag and swell.

II.SOLAR POWER SYSTEM

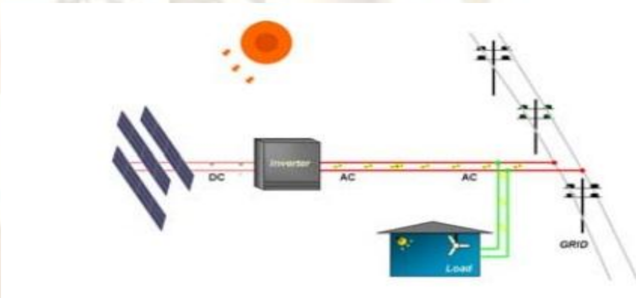

Fig.1. solar power system.

The general block diagram of grid connected PV system is shown in Fig.1 and the system can be a single phase or three phase depending on the grid connection requirements. The PV array can be a single or a string of PV panels either in series or parallel mode connection. Centralized or decentralized mode of the PV systems can also be used and the overview of these PV-inverter – grid connection topologies along with their advantages and disadvantages are discussed.

In general, a grid connected PV system inverter is not able to control the reactive and harmonic currents drawn from non-linear loads. An interesting controlling mechanism has been presented in where a PV system is used as an active filter to compensate the reactive and harmonic current as well as injecting power to the grid. The system can also operate in standalone mode. But the overall circuit becomes somewhat complex.

III. OPERATING PRINCIPLE OF THE DSTATCOM

Basically, the DSTATCOM system is comprised of three main parts: a Voltage Source Converter (VSC), a set of coupling reactors and a controller . The basic principle of a DSTATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source inverter(VSI) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance.

The active and reactive power transfer between the power system and the DSTATCOM is caused by the voltage difference across this reactance. The DSTATCOM is connected to the power networks where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT' s, which are used at the distribution level) of the power converter accordingly. The basic diagram of the DSTATCOM is illustrated in Fig.2.

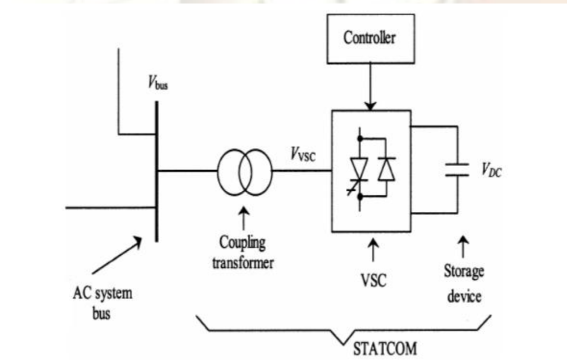

Fig.2. Block Diagram of the voltage source converter based DSTATCOM

The AC voltage control is achieved by firing angle control. Ideally the output voltage of the VSI is in phase with the bus(where the DSTATCOM is connected.) voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses. The DSTATCOM differs from other reactive power generating devices (such as shunt Capacitors, Static Var Compensators etc.) in the sense that the ability for energy storage is not a rigid necessity but is only required for System unbalance or harmonic absorption.

There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at the bus where the DSTATCOM is connected. And the other is dc voltage control across the capacitor inside the DSTATCOM. It is widely known that shunt reactive power injection can be used to control the bus voltage. In conventional control scheme, there are two voltage regulators designed for these purposes. ac voltage regulator for bus voltage control and dc voltage regulator for capacitor voltage control. In the simplest strategy, both the regulators are proportional integral (PI) type controllers.

IV. MODELLING OF PV ARRAY

The building block of PV arrays is the solar cell, which is basically a p-n junction that directly converts light energy into electricity. it has a equivalent circuit as shown below in Fig.3.

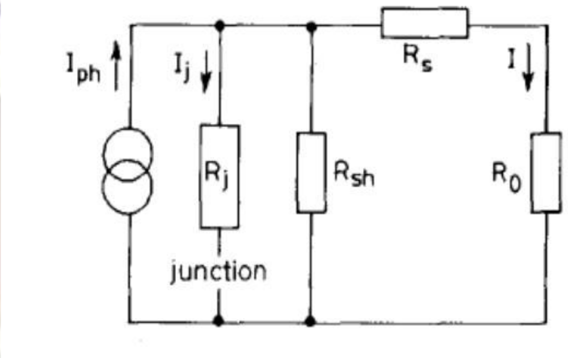

Fig.3. Equivalent circuit of a PV cell

The current source Iph represents the cell photo current. Rj is used to represent the non-linear impedence of the p-n junction. Rsh and Rs are used to represent the intrinsic series and shunt resistance of the cell respectively. Usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in series-parallel configuration to form PV arrays or PV generators.

The PV mathematical model used to simplify our PV array is represented by the equation,

$$I = n_p I_{ph} - n_p I_{rs} [\exp\{(q/KTA)*(V/n_s)\} - 1]$$

where I is the PV array output current. V is the PV array output voltage. n_s is the number of cells in series and n_p is the number of cells in parallel. q is the charge of an electron. k is the Boltzmann's constant. A is the p-n junction ideality factor. T is the cell temperature (K). Irs is the cell reverse saturation current.

The cell reverse saturation current Irs varies with temperature according to the following equation,

$$I_{rs} = I_{rr} \ [T/T_r]^3 \exp\{qE_G / KA \ [(1/T_r) - (1/T)]\}$$

Where Tr is the cell reference temperature, Irr is the cell reverse saturation temperature at Tr and EG is the band gap of the semiconductor used in the cell.

The temperature dependence of the energy gap of the semi conductor is given by

$$E_G = E_G(0) - (\alpha T^2 / T + \beta)$$

The photo current Iph depends on the solar radiation and cell temperature as follows,

$$I_{ph} = [I_{scr} + K_i (T - T_r)] s/100$$

where Iscr is the cell short circuit current at reference temperature and radiation, Ki is the short circuit current temperature coefficient, and S is the solar radiation in mW/cm^2.

The PV power can be calculated using equation as follows,

$$P = IV = n_P I_{ph} V\{[(q/KTA)^* (V/n_s) - 1]\}$$

V. MODELLING OF DSTATCOM

The compensation of voltage sag/swell can be limited by a number of factors, including finite DSTATCOM power rating, loading conditions, power quality problems and types of sag/swell. If a DSTATCOM is a successful device, the control is able to handle most sags/swells and the performance must be maximized according to the equipment inserted. Otherwise, the DSTATCOM may not be able to avoid tripping and even cause additional disturbances to the loads.

1. Mathematical Modeling for Voltage Injection by DSTATCOM

Consider the schematic diagram shown in Fig.3.

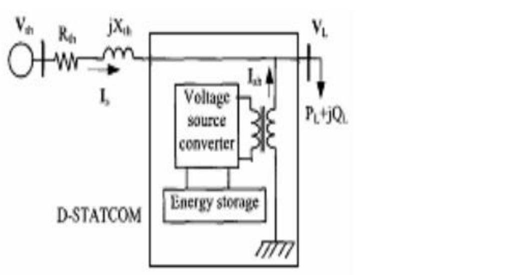

Fig.4. Calculation for DSTATCOM voltage injection

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Fig.3 consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device in to a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes,

1. Voltage regulation and compensation of reactive power.
2. Correction of power factor.
3. Elimination of current harmonics.

Here, such device is employed to provide continuous Voltage regulation using an indirectly controlled converter.

Fig.3. the shunt injected current Ish corrects the voltage sag by adjusting the voltage drop across the system impedance Zth. The value of Ish can be controlled by adjusting the output voltage of the converter.

The shunt injected current Ish can be written as,

$$I_{sh} = I_L - I_S$$

$$I_{sh} = I_L - [(V_{Th} - V_L)/Z_{Th}]$$

$$I_{sh} \angle\eta = I_L \angle -\theta - (V_{th}/Z_{th})\angle(\delta-\beta) + (V_L/Z_{th})\angle -\beta$$

The complex power injection of the DSTATCOM can be expressed as,

$$S_{sh} = V_L I_{sh}$$

It may be mentioned that the effectiveness of the DSTATCOM in correcting voltage sag depends on the value of Zth or fault level of the load bus. When the shunt injected current Ish is kept in quadrature with V_L the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of Ish is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system.

VI SIMULATION RESULTS

The functioning of a photovoltaic array is impacted by temperature, solar irradiance, shading, and array configuration. Frequently, the PV arrays get shadowed, wholly or partially, by the moving clouds, adjacent buildings and towers, trees, utility and telephone poles. The situation is of especial interest in case of big PV installations such as those used in distributed power generation systems. Under partly shaded conditions, the photovoltaic characteristics get more complex with more than one peaks. Yet, it is very crucial to understand and predict them in order to draw out the maximum possible power. Here, we present a MATLAB-based modeling and simulation scheme. DSTATCOM plays a vital role as a compensating

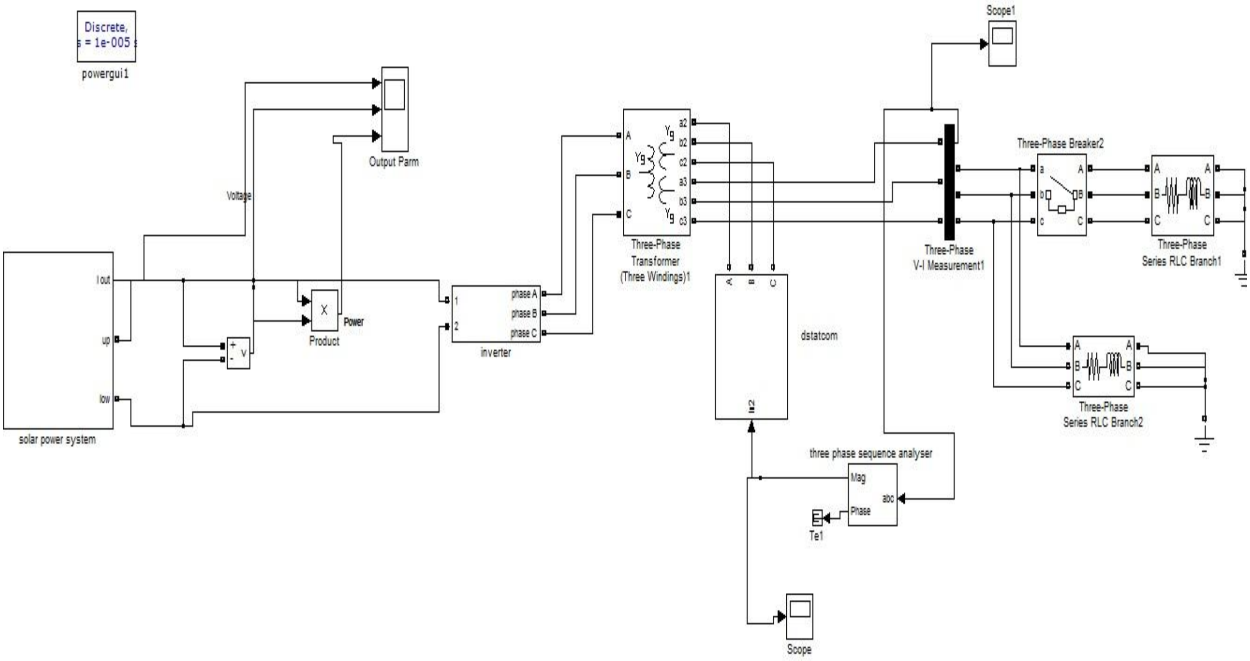

Fig.5. Simulink Model of PV Array with Distribution section

device in the distribution side. Basically, DSTSTCOM consists of PWM (Pulse With Modulation) Voltage source inverter circuit and a DC capacitor connected at one end. In the Distribution voltage level, the switching element is usually the integrated gate bipolar transistor (IGBT), due to its lower switching losses and reduced size. Moreover, the power rating of custom power devices is relatively low .Consequently , the output voltage control may be executed through the pulse width modulation (PWM) switching method. IGBT based PWM inverter is implemented using Universal bridge block from Power Electronics subset of Sim Power Systems. RC snubber circuits are connected in parallel with each IGBT for protection. Such a model consists of a six-pulse voltage-source converter using IGBTs/diodes, a 19000Vdc capacitor , a PWM signal generator with switching frequency equal to 3 kHz, After modeling of DSTATCOM, It is applied to a Three phase three winding step down transformer connecting to different loads.

Capacity of the 3 phase voltage source 230 KV, and frequency 50Hz, and it is connected with three phase three winding step down transformer. The primary winding is connected to the 230 KV in Fig.5. DSTATCOM is connected with secondary winding. And the purpose the transformer is to step down the 230KV to 11KV without changing of its frequency and it is directly connected to the three phase RLC (Resistance, Inductance, Capacitance) Loads.

The fault is occur in the over loading of the end-user, i.e. voltage sag, if the loading is constantly supplied, but the voltage input becomes higher then it is called as voltage swell. And these are the main problems which seriously damage the system with great economic loss.

By usage of the compensating device (DSTATCOM) in the system consequences the problem rectifies and the system gives a efficient economic constraint to the end-user.

1. VOLATAGE SAG (Without DSTATCOM)

There is no compensating device which is connected in this simulation .And the results which we obtained in graph contains X-axis (time-sec) and Y- axis (Vrms - p.u).The voltage sag occurs in period of 0.11sec - 0.32 sec. the graph shows the voltage gradually increased with time and because of the overvoltage such as sudden increase of load and after the sag occurs. It maintains a constant pathway.

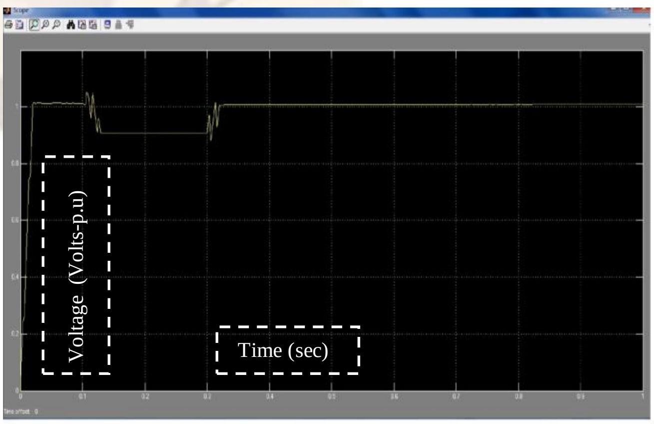

Fig.6. Voltage Sag Without DSTATCOM

2. VOLTAGE SAG (With DSTATCOM)

In this simulation , there is a compensating device which is connected in the system. So because of this compensating device , it rectifies the voltage sag fault occurs previously.

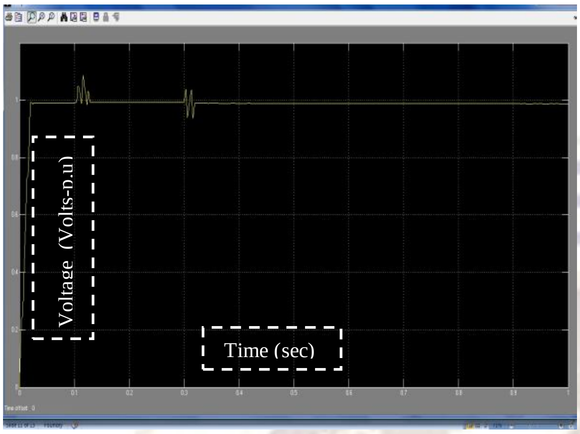

Fig.7. Voltage Sag With DSTATCOM

3. VOLTAGE SWELL(without DSTATCOM)

There is no compensating device which is connected in this simulation And the results which we obtained in graph contains X-axis (time-sec) and Y- axis (Vrms - p.u).The voltage swell occurs in period of 0.11sec - 0.32 sec.

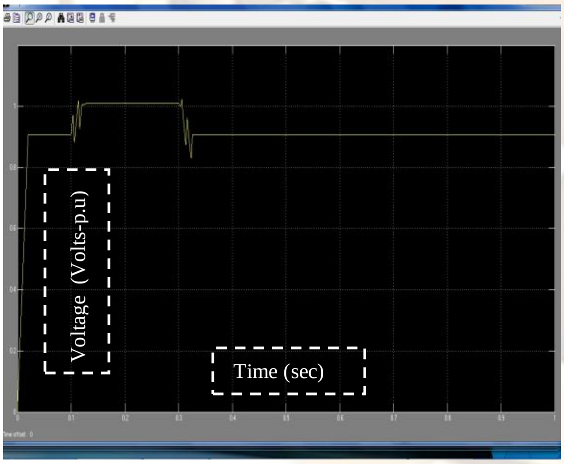

Fig.8. Voltage Swell Without DSTATCOM

4.VOLATAGE SWELL (with DSTATCOM)

In this simulation , there is a compensating device which is connected in the system. So because of this compensating device , it rectifies the voltage swell fault occurs previously.

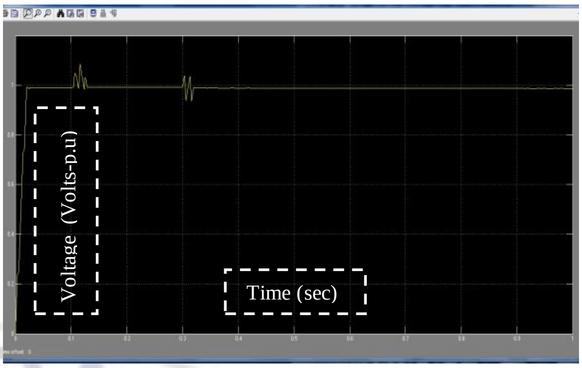

Fig.9. Voltage Swell Without DSTATCOM

VII. PARAMETRS OF DSTATCOM

Table1. Parameters of DSTATCOM

DC Voltage Source	19 x 10^3 volts
Series RLC Branch resistance	5 x 10^{-2} ohms
Parallel RLC Branch capacitance	750 x 10^{-6} Faraday
Snubber Resistance (Rs) of universal bridge	1 x 10^5ohms
Discrete PWM Generator	3 arms, 6 pulse, 50Hz
3 phase breaker snubber resistance (Rp)	1 x 10^6ohm

VIII. PARAMETERS OF POWER SYSTEM

Table 2. Parameters of Power System

3 phase source	230 KV, 50 Hz
3 phase transformer – nominal power and frequency	100 x 10^6, 50Hz
3 phase transformer	Winding 1- 230KV, R-0.002 ohms, L-0.08H Winding 2- 11 x 10^3 , R-0.002ohms, L- 0.08H Winding 3- 11 x 10^3, R-0.002ohms, L- 0.08H
3 phase breaker (Resistance, snubber resistance Rp)	0.001 ohms, Ix10^6ohms.
Load 1	R – 25.1ohms, L – 300x10^{-3}H
Load 2	R – 0.05 ohms, L – 25 x 10^{-3}H
Fundamental frequency of sequence analyzer	50Hz

IX.CONCLUSIONS

The power quality problems of Solar Power Distributed in high voltage transmission lines are been detected and the voltage sag, voltage swell problems are occurred and by using compensating device like DSTATCOM. it rectifies the corresponding problems and briefly discussed in above discussions. Thus we concluded, the usage of compensating device like DSTATCOM gives a greater advantage to solve these problems occurs in power quality.

REFERENCES

1. Aamir Hanif and Mohammad Ahmad Choudhry[2008] Department of Electrical Engineering University of Engineering and Technology Taxila, 47050 Pakistan Investigating Voltage Restoration And Power Export In A Distribution System With Series Compensator Using Distributed Generation..
2. Eduardo F. Camacho, Tariq Samad, Mario Garcia-Sanz, and Ian Hiskens -Control for Renewable Energy and Smart Grids.
3. Gao Xiaozhi, Li Linchuan, and Chen Wenyan 2011Key Laboratory of Power System Simulation and Control of Ministry of Education, Tianjin University, Tianjin 300072, China. Power Quality Improvement for Mircro grid in Islanded Mode.
4. Huo-Ching Suna, Yann-Chang Huanga, Chao-Ming Huang[2012] a Department of Electrical Engineering, Cheng Shiu University, Kaohsiung, TAIWAN Department of Electrical Engineering, Kun San University, Tainan, TAIWAN Fault Diagnosis of Power Transformers Using Computational Intelligence: A Review.
5. Hari Prasad.A ,International Journal of Scientific & Engineering Research Volume 2, Issue 10, Oct-2011 1ISSN 2229-5518Photovoltaic Cell as Power Quality conditioner for Grid connected system
6. Jianwu Cao[2011] Florida State University Analysis and Implementation of Grid-Connected Solar PV with Harmonic Compensation
7. Minas Patsalides, Demetres Evagorou, and George Makrides [2007], 1Department of Electrical and Computer Engineering, University of Cyprus, The Effect of Solar Irradiance on the Power Quality Behaviour of Grid Connected Photovoltaic Systems.
8. Minas Patsalides, Andreas Stavrou, and Venizelos Efthimiou, [2007] Department of Electrical and Computer Engineering, University of Cyprus 75 Kallipoleos Avenue, P.O. Box 20537 Nicosia, 1678, Cyprus Assessing the level of Harmonic Distortion due to PV generation in Mini Grids.
9. Manish Kumar Saini, Rajiv Kapoor[2012] a Electronics & Communication Engineering Department, Delhi Technological University, New Delhi, India, Electrical Engineering Department, Deenbandhu Chhotu Ram University of Science & Technology, Sonepat, India Classification of power quality events – A review Power Quality Measurement. hioki E.E Corporation
10. Ozgur Gencer, Semra Ozturk, Tarık Erfidan Kocaeli University, Faculty of Engineering, Department of Electrical Engineering, Vezirog˘lu Kampüsü, Eski Gölcük Yolu, Kocaeli, Turkey A new approach to voltage sag detection based on wavelet transform.
11. Parth Amin B.E., Gujarat University, India, 2007, Power Generation Using Solar Power Plant.
12. Patil.D.R & Komal K.Madhale [2008]Walchand college of Engg. E-mail : dadasorpatil@gmail.com, madhale_k@yahoo.com Design And Simulation Studies of D-Statcom For Voltage Sag, Swell Mitigation.
13. Parag Nijhawan, Ravinder Singh Bhatia, and Dinesh Kumar Jain [2012] Electrical and Instrumentation Engineering Department, Thapar University, Patiala, India.2 Electrical Engineering Department, National Institute of Technology, Kurukshetra, India. Application of PI controller based DSTATCOM for improving the power quality in a power system network with induction furnace load.
14. Rajesh Thipparapu P.G. scholar, Dept of EEE SCC Engg, Karimnagar Rajesh Thipparapu, Prashanth Neelugonda, D.Bhanumurthy/ International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.970-975 Power Quality Improvement at Distribution Level for Grid connected Renewable Energy Sources.
15. Sanae Rechka, Éloi Ngandui, Jianhong Xu, Pierre Sicard[2003]Hydro-Québec Research Chair on Power and Electrical and Computer Engineering, Department of Electrical and Computer Engineering, Université du Québec à Trois-Rivières, C.P. 500 Trois-Rivières, Que., Canada G9A5H7 Performance evaluation of harmonics detection methods applied to harmonics compensation in presence of common power quality problems.

16. Tejas Zaveri, B.R. Bhalja and, Naimish Zaveri a Faculty of Engineering & Technology, Veer Narmad South Gujarat University, Surat 395 007, Gujarat, India b Department of Electrical Engineering, A.D. Patel Institute of Technology, New Vallabh Vidyanagar 388 121, Gujarat, Indiac Electrical Engineering Department, C.K. Pithawalla College of Engineering & Technology, Surat 395 007, Gujarat, India Load compensation using DSTATCOM in three-phase, three-wire distribution system under various source voltage and delta connected load conditions.
17. Technical Note 10 October 2011 Endeavour Energy Power Quality & Reliability Centre Small Scale Domestic Rooftop Solar Photovoltaic Systems.
18. Tiwari H.P, Sunil Kumar Gupta International Journal of Innovation, Management and Technology, Vol. 1, No. 1, April 2010 ISSN: 2010-0248 Dynamic Voltage Restorer Based on Load Condition.