International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

A New Approach for Design and Analysis ofVoltage-Controlled DSTATCOM

Cholleti Priyanka
M.Tech, PEED
Ravula Srikanth
Asst. Professor, EEE
Sahasra College Of Engineering For Women, Warangal

ABSTRACT: This project tends look at the solving the sag problems by usingcustom power devices such as Distribution Static compensator (D-STATCOM).Proposed scheme follows a newalgorithm to generate reference voltage for a distribution static compensator (DSTATCOM) operating involtage-control mode. The proposed scheme ensures that unity power factor (UPF) is achieved at the loadterminal during nominal operation, which is not possible in the traditional method. Also, the compensatorinjects lower currents therefore, reduces losses in the feeder and voltage-source inverter. Further, a saving inthe rating of DSTATCOM is achieved which increases its capacity to mitigate voltage sag. Nearly UPF ismaintained, while regulating voltage at the load terminal, during load change. The state-space model ofDSTATCOM is incorporated with the deadbeat predictive controller for fast load voltage regulation duringvoltage disturbances. With these features, this scheme allows DSTATCOM to tackle power-quality issues byproviding power factor correction, harmonic elimination, load balancing, and voltage regulation based on theload requirement.

KEYWORDS-DSTATCOM, power quality, Reactive power compensation,power control and power quality.

I. INTRODUCTION

One of the most common power quality problems today isvoltage dips. A voltage dip is a short time (10 ms to 1minute) event during which a reduction in r.m.s voltagemagnitude occurs. It is often set only by two parameters,depth/magnitude and duration. The voltage dip magnitude isranged from 10% to 90% of nominal voltage (whichcorresponds to 90% to 10% remaining voltage) and with aduration from half a cycle to 1 min. In a three-phase systema voltage dip is by nature a three-phase phenomenon, whichaffects both the phase-to-ground and phase-to-phasevoltages. A voltage dip is caused by a fault in the utilitysystem, a fault within the customer‟s facility or a largeincrease of the load current, like starting a motor or transformer energizing. Typical faults are single-phase ormultiple-phase short circuits, which leads to high currents.The high current results in a voltage drop over the networkimpedance. At the fault location the voltage in the faultedphases drops close to zero, whereas in the non-faultedphases it remains more or less unchanged [1, 2].Voltage dips are one of the most occurring powerquality problems. Off course, for an industry an outage isworse, than a voltage dip, but voltage dips occur more oftenand cause severe problems and economical losses. Utilitiesoften focus on disturbances from end-user equipment as themain power quality problems. This is correct for manydisturbances, flicker, harmonics, etc., but voltage dipsmainly have their origin in the higher voltage levels. Faultsdue to lightning, is one of the most common causes tovoltage dips on overhead lines. If the economical losses dueto voltage dips are significant, mitigation actions can beprofitable for the customer and even in some cases for theutility. Since there is no standard solution which will workfor every site, each mitigation action must be carefullyplanned and evaluated. There are different ways to mitigatevoltage dips, swell and interruptions in transmission anddistribution systems. At present, a wide range of veryflexible controllers, which capitalize on newly availablepower electronics components, are emerging for custompower applications [3, 4]. Among these, the distributionstatic compensator and the dynamic voltage restorer aremost effective devices, both of them based on the VSCprinciple.

Due to increased current injection, the VSI is de-rated insteady-state condition. Consequently, its capability tomitigate deep voltage sag decreases. Also, UPFcannotbeachievedwhenthePCCvoltageis1p.u.Inth eliterature,so far, the operation of DSTATCOM is not reported wherethe advantages of both modes are achieved based on loadrequirements while overcoming their demerits.This paper considers the operation of DSTATCOM in VCMand proposes a control algorithm to obtain the referenceload terminal voltage. This algorithm provides thecombined advantages of CCM and VCM. The UPFoperation at the PCC is achieved at nominal load, whereasfast voltage regulation is provided during voltagedisturbances. Also, the reactive and harmonic component ofload current is supplied by the compensator at any time ofoperation. The deadbeat predictive controller [15]–[17] isused to generate switching pulses. The control strategy istested with a three-phase four-wire distribution system. Theeffectiveness of the proposed algorithm is validated throughdetailed simulation and experimental results

II. POWER QUALITY AND RELIABILITY

Power quality and reliability cost the industry largeamounts due to mainly sags and short-term interruptions.Distorted and unwanted voltage wave forms, too. Here we define the reliability as thecontinuity of supply. As shown in Fig.1, the problem ofdistribution lines is divided into two major categories. Firstgroup is power quality, second is power reliability. Firstgroup consists of harmonic distortions, impulses and swells.Second group consists of voltage sags and outages. Voltagesags is much more serious and can cause a large amount ofdamage. If exceeds a few cycle, motors, robots, servo drivesand machine tools cannot maintain control of process.

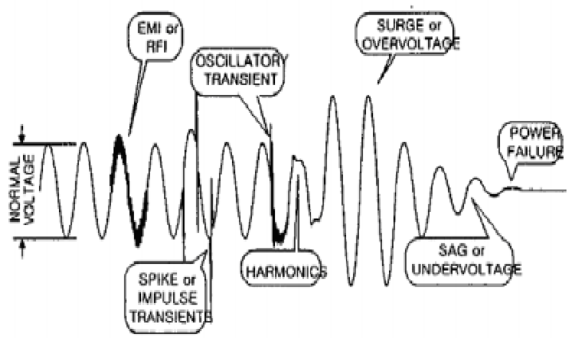

Fig.1. power quality and reliability

Both the reliability and quality of supply are equallyimportant. For example, a consumer that is connected to thesame bus that supplies a large motor load may have to face asevere dip in his supply voltage every time the motor load isswitched on. In some extreme cases even we have to bearthe black outs which is not acceptable to the consumers.There are also sensitive loads such as hospitals (life support,operation theatre, and patient database system), processingplants, air traffic control, financial institutions and numerousother data processing and service providers that requireclean and uninterrupted power. In processing plants, a batchof product can be ruined by voltage dip of very shortduration. Such customers are very wary of such dips sinceeach dip can cost them a substantial amount of money. Evenshort dips are sufficient to cause contactors on motor drivesto drop out. Stoppage in a portion of process can destroy theconditions for quality control of product and requirerestarting of production. Thus in this scenario in whichconsumers increasingly demand the quality power, the

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

termpower quality (PQ) attains increased significance.

Transmission lines are exposed to the forces of nature.Furthermore, each transmission line has its load ability limitthat is often determined by either stability constraints or bythermal limits or by the dielectric limits. Even though thepower quality problem is distribution side problem,transmission lines are often having an impact on the qualityof the power supplied. It is however to be noted that whilemost problems associated with the transmission systemsarise due to the forces of nature or due to the interconnectionof power systems, individual customers are responsible formore substantial fraction of the problems of powerdistribution systems.

III. PROPOSED CONTROL SCHEME

Power regulation in a Distributed Power System (DPS) is atrival and most important task, which affects the quality ofpower being supplied from the DPS. The power and voltagelevels from the DPS may get disturbed by several factorslike line impedance variations due to ageing of the line,increased heat during summer, unnecessary snow and rainfall, corrosion, thunders and storms. But all the applicationswhich rely for their operation on electrical power from theDPS required the power to be supplied at the required ratedlevel. The power quality of the Power Distribution LineBus(PDLB) may get fluctuated due to a sudden variation inthe load impedance, source current levels and input powerfluctuations. Whatever it may be the reason for powerfluctuation, but the utilities of electrical energy from theDPS cannot continue normal operation, there by demanding regulated rated power quality for lossless and destructionless operation of their internal discrete components. Thusregulations of power levels from the DPS are the mostimportant task and to perform that task, several methodswere proposed in the literature. But among them we foundthat the Distributed static compensator is best inperformance in all aspects compared to all other existingtechniques. Since from the operational knowledge of theDSTATCOM we found that, the salient performancefeatures of DSTATCOM are steered by the proper selectionof appropriate threshould/reference voltage. TheDSTATCOM offers best of its performance if the referencevoltage was selected appropriately, otherwise itsperformance may not be satisfactory. Hence properselection of reference voltage for the DSTATCOM decidesthe effectiveness of DSTATCOM in distributed powerregulation activities. In this project we are going to designthe reference voltage for the DSTATCOM which isdesigned and implemented using fuzzy logic and beingoperated in the control mode. The Circuit diagram of aDSTATCOM -compensated distribution system is shown inFig(1). It uses a three- phase, four-wire, two-level,neutralpoint-clamped Voltage Switching Inverter (VSI).Thisstructure allows independent control to each leg of the VSI[7].

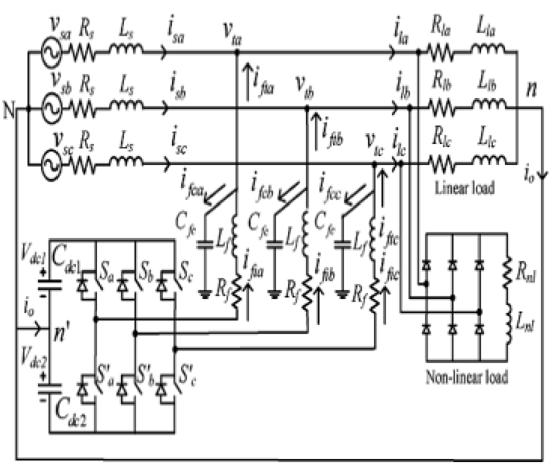

Fig.2: Circuit diagram of the DSTATCOMcompensated distribution system.

Fig.(3) shows the single-phase equivalent representationof Fig.(2). Variable "U" is a switching function, and can beeither +1 or -1 depending upon switching state. Filterinductance and resistance are $L_f$andR_f, respectively.Shunt capacitor $C_f$eliminates high-switching frequencycomponents. First, discrete modeling of the system ispresented to obtain a discrete voltage control law, and it isshown that the

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

PCC voltage can be regulated to the desiredvalue with properly chosen parameters of VSI. Then, aprocedure to design VSI parameters is presented. Aproportional-integral (PI) controller is used to regulate thedc capacitor voltage at a reference value.

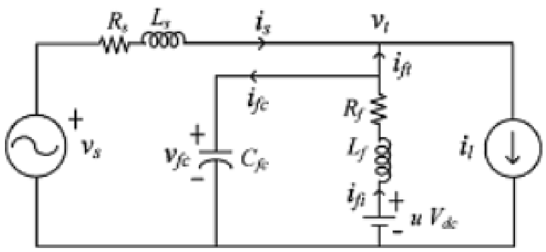

Fig.3: Single-phase equivalent circuit of DSTATCOM

Basedon instantaneous symmetrical component theory andcomplex Fourier transform, a reference voltage magnitudegeneration scheme is proposed that provides the advantagesof CCM at nominal load. The overall controller blockdiagram is shown in Fig (4).

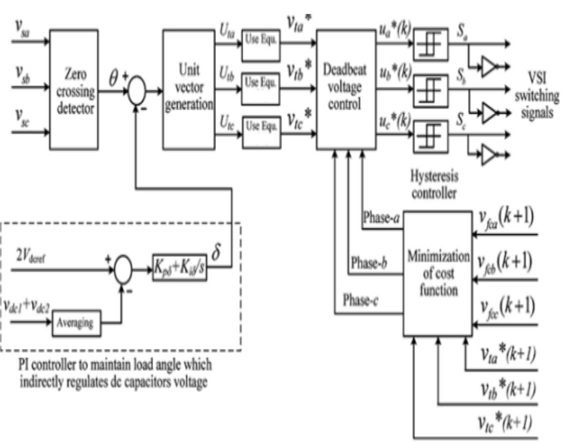

Fig.4: Overall block diagram of the controller to control DSTATCOM in a distribution system

The state-space equations for the circuit shown in Fig (3)are given by

$$x = Ax + Bz \rightarrow (1)$$

Where

$$A = \begin{bmatrix} 0 & \frac{1}{C_{fc}} & 0 \\ \frac{-1}{L_f} & \frac{-R_f}{L_f} & 0 \\ \frac{-1}{L_s} & 0 & \frac{-R_s}{L_s} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & -\frac{1}{C_{fc}} & 0 \\ \frac{V_{dc}}{L_f} & 0 & 0 \\ 0 & 0 & \frac{1}{L_s} \end{bmatrix}$$

$$x = [V_{fi} i_{fi} i_s]^t$$

$$z = [u\, i_{ft} v_s]^t$$

The general time-domain solution of equation (1) tocompute the state vector x(t) with known initial value x(t0)is given as follows:

$$x(t) = e^{A(t-t_0)}\, x(t_0) + \int_{t_0}^{t} e^{A(t-\tau)} Bz(\tau)d\tau \rightarrow (2)$$

The equivalent discrete solution of the continuous state isobtained by replacing t0=kTd and t=(k+1)Td as follows:

$$x(k+1) = e^{AT_d}\, x(k) + \int_{kt_d}^{T_d+kT_d} e^{A(T_d+kT_d-\tau)} Bz(\tau)d\tau \rightarrow (3)$$

Where k and T_d represents the k^{th} sample and samplingperiod respectively. During the consecutive samplingperiod, the value of z(τ) is held constant, and can be takenas z(k). After simplification and changing the integrationvariable, equation (3) can be written as

$$x(k+1) = e^{AT_d} + \int_0^{T_d} e^{A\lambda} B d\lambda z(k) \rightarrow (4)$$

This equation is written as follows:

x(k+1)=Gx(k)+ Hz(k) → (5)

where H and G are sampled matrices, with the sampling time of T_d. For small sampling time G and H are calculated as follows:

$$G = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ G_{21} & G_{22} & G_{23} \\ G_{31} & G_{32} & G_{33} \end{bmatrix} = e^{AT_d} \approx 1 + AT_d + \frac{A^2T_d^2}{2} \rightarrow (6)$$

$$H = \begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & H_{33} \end{bmatrix} = \int_0^{T_d} e^{A\lambda} B d\lambda \approx \int_0^{T_d} (1 + \lambda) B d\lambda \rightarrow (7)$$

Hence the capacitor voltage is given by

$$v_{fc}(k+1) = G_{11}v_{fc}(k) + G_{12}i_{fi}(k) + H_{11}u(k) + H_{12}i_{ft}(k) \rightarrow (8)$$

As seen from eq(8), the terminal voltage can be maintained at a reference value depending upon the VSI parameters V_{dc}, C_{fc}, L_f, R_f and sampling time T_d. therefore, VSI parameters must be chosen carefully. Let v_t^* be the referece load terminal voltage. A cost J is chosen as follows.

$$J = [v_{fc}(k+1) - v_t^*(k+1)]^2 \rightarrow (9)$$

The cost function is differentiated with respect to u(k) and its minimum is obtained at

$$v_{fc}(k+1) = v_t^*(k+1) \rightarrow (10)$$

The deadbeat voltage-control law, from (8) and (10), is given as

$$u^* = \frac{v_t^*(k+1) - G_{11}v_{fc}(k) - G_{12}i_{fi}(k) - H_{12}i_{ft}(k)}{H_{11}} \rightarrow (11)$$

The schematic overall block diagram of the proposed controller to control the DSTATCOM in distributed powersystem is shown in fig(3),which consists of a zero crossingdetector which detects the zero crossing points in threephasor voltage waveforms. Using the result from the zerocrossing detector and load angle from the PI controller tomaintain dc capacitor voltage, the Unit Vector Generator(UVG) generates three unit threshould vectors for threephasor voltage lines of the DSTATCOM which will befurther optimized according to the characteristic equation

$$V_t^* = \sqrt{V^2 - (|\overline{I^+}|X_s)^2} - |\overline{I^+}|R_s \rightarrow (12)$$

IV. SIMULATION RESULTS

The practical implementation of the proposed algorithm forgenerating the reference voltage of the Distributive StaticCompensator (DSTATCOM) operating in the control modefor voltage stability control and analysis of a distributedpower system is done by designing the correspondingSimulink models hierarchically to replicate variousprocessing stages involved in designing the DSTATCOMand various processing models usingMATLAB/SIMULINK software. The proposed algorithmwill includes the design and analysis of variousDSTATCOM models as given under.

V. CONCLUSION

The performance of the proposed scheme is compared with the traditional voltage controlledDSTATCOM. The proposed method provides the following advantages- at nominal load, the compensatorinjects reactive and harmonic components of load currents, resulting in UPF; nearly UPF is maintained for aload change; fast voltage regulation has been achieved during voltage disturbances and losses in the VSI andfeeder are reduced considerably, and have higher sag supporting capability with the same VSI rating comparedto the traditional scheme. Different types of voltage sag conditions should applied compensated in Simulink environment. Additionally power factor correction and voltage regulation the harmonics are also checked, 20%voltage sag eliminated under t=0.5 to 1sec, thus the simulation results show that the proposed scheme providesDSTATCOM, a capability to improve several Power Quality problems (related to voltage and current).

REFERENCES

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 12
August 2016

[1] A.E. Hammad, Comparing the Voltage sourcecapability of Present and future Var CompensationTechniques in Transmission System, IEEE Trans, onPower Delivery. Volume 1.No.1 Jan 1995.

[2] G.Yalienkaya, M.H.J Bollen, P.A. Crossley,"Characterization of Voltage Sags in IndustrialDistribution System", IEEE transactions on industryapplications, volume 34, No. 4, July/August, PP.682-688, 1999.

[3] Haque, M.H., "Compensation of Distribution SystemsVoltage sags by DVR and D-STATCOM", PowerTech Proceedings, 2001 IEEE Porto, Volume 1,PP.10-13, September 2001.

[4] Anaya-Lara O, Acha E., "Modeling and Analysis OfCustom Power Systems by PSCAD/EMTDC", IEEETransactions on Power Delivery, Volume 17, Issue:2002, Pages: 266-2725.

[5] "Power Quality Enhancement with DSTATCOM for SmallIsolated Alternator feeding Distribution System" by BhimSingh, Department of Electrical Engineering, Indian Instituteof Technology, HauzKhas, New Delhi.

[6] "FACTS and custom power equipment for the enhancementof power transmission system performance and powerquality" by John J. Paserba, Gregory F. Reed Mitsubishielectric power products, inc.. Warren dale, Pennsylvania,U.S.A, Masatoshi takeda and tomoshikoAritsuk, MitsubishiElectric Corporation, Japan

[7] Benefits of SVC and STATCOM for Electric UtilityApplication" by M. Noroozian, SM IEEE Åke, N Petersson,B. Thorvaldson, Bo A. Nilsson ABB Utilities, FACTSDivision, Västerås, Sweden and C.W. Taylor, Fellow IEEECarson Taylor Seminars Portland, Oregon USA.

[8] "An alternative cost-effective applications of power factorcorrection" by Richard A. Flusher, member, IEEE[9] "Operation of a DSTATCOM in Voltage Control Mode" byMahesh K. Mishra, Student Member, IEEE, ArindamGhosh,Senior Member, IEEE, and Avinash Joshi

[10] "The role, of custom power products In enhancing powerquality at industrial facilities" by Michael D. Stump, P.E.Westinghouse generation Gerald J. Keane PowerWestinghouse and Frederick K. S. Leong PowerWestinghouse Industry Services Asia private limited

[11] "Modeling, Analysis and Performance of a DSTATCOM forUnbalanced and Non-Linear Load" by Dinesh Kumar,Rajesh

[12] "Voltage Sag and Swell Generator for the Evaluation ofCustom Power Devices" by Y.H. Chrmg. G.H Kwon T.B.Park and K. Y Lim

[13] "Voltage Flicker Mitigation Using PWM-Based DistributionSTATCOM" by J. Sun, Student Member, IEEE, D.Czarkowski, Member, IEEE, and Z. Zabar, Senior Member,IEEE

[14] "Power Quality enhancement using custom power devices"by ArindamGhosh and Gerard Ledwich .

[15] J. Rodriguez, J. Pontt, C. A. Silva, P. Correa, P.Lezana, P. Cortes, and U. Amman, "Predictive currentcontrol of a voltage source inverters,"IEEE Trans. Ind.Electron., vol. 54, no. 1, pp. 495–503, Feb. 2007.

[16] J. Barros and J. Silva, "Multilevel optimal predictivedynamic voltage restorer," IEEE Trans. Ind. Electron.,vol. 57, no. 8, pp. 2747–2760, Aug. 2010.

[17] O. Kukrer, "Discrete-time current control of voltagefed three-phase PWM inverters,"IEEE Trans. PowerElectron., vol. 11, no. 2, pp.260–269, Mar. 1996.

Authors:

Cholleti Priyanka pursing M.Tech in PEED from sahasra college of engineering for women, warangal.

Ravula Srikanth working as Asst. Professor, Electrical and Electronics Engg. Dept, in sahasra college of engineering for women, warangal, Telangana, India.