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Application of D-Statcom for Isolated Systems

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Abstract: This paper demonstrates a model of distribution staticcompensator D-STATCOM controller connected to an isolatedsystem. Simulation is performed using Power System Toolboxes andSimulink of standard MATLABsoftware. Two simple PI controllersare used to offer DC bus voltage control and ac bus voltageregulation at the point of common coupling. Results are obtainedfor D-STATCOM applied to a simple isolated distribution systemwhen it is connected to an alternator. D-STATCOM is an importantshunt controller that has the potential to solve power qualityproblems faced by distribution systems. Results show that DSTATCOMis able to regulate unity power factor correction andprovide voltage regulation.

Keywords: M-STATCOM, DCbus voltage, D-STATCOM, voltage regulation, MATLAB,

1.Introduction:

Generating plant sizes of the order of 2000 MW have been quitecommon in the last century. A new trend emerging nowadays is thedevelopmentofsignificantly smaller sized plants dedicated to smallor medium sizedindustrialloads.Smalldistributiongeneratorsarenowadays commonly used in parallel with the normal gridconnected power systems. These sets generally supply emergencypower in the need of hour. However, completely isolated powersystems are gaining increased importance in electric power systemson ships, aircrafts, off shore plants, power distribution in islands etc[1].Small-dedicated systems installed at the customer premises andcatering only tolocalloadshasgainedalot of awareness.Conventional FlexibleACTransmissionsystemdevices (FACTS)like Static Var Compensators (SVC) have been around for a longtime. Advances in power electronic devices andtechnologyhavegivenrisetoThyristorControlledReactor (TCR),ThyristorSwitched Capacitor(TSC)and Static Compensator(STATCOM) Distribution Static Compensator(D-STATCOM)isakeyFACTScontroller and it utilizes power electronics to solve many powerquality problems commonly faced by distribution systems. Potentialapplications of D-STATCOM include power factor correction,voltage regulation, load balancing and harmonic reduction. Use ofD-STATCOM with utility grid connected as source has been studiedhowever very little work has been done related to application ofD-STATCOM to systems isolated from the utility grid. This paperpresents D-STATCOM connected to an isolated system when it isconnected to an alternator[1].In this paper,modelingofDSTATCOMiscarriedoutinMATLABenvironmentusingSimulinkandPowersystemBlocksettoimplement the power circuit as well as the control circuit.A3.125MVA, 60Hz synchronous alternator acts as source for thesystem load drawing lagging power factor current. D-STATCOMhas the abilitytoprovideimmediatereactivepowercompensationsystem and improve the voltage profile of the system. This shuntdevice can also cancel the effect of unbalanced load currents suchthat the current drawn from the source is balanced and also at unitypower factor with the source voltage.

2. D-Statcom Configuration:

D-STATCOM is a solid state DC- AC switching power converterthat consists of a three-phase voltage sourced inverter (VSI) bridgehaving six IGBT switches. It is connected to the distributionnetwork via the impedance of

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the coupling transformer. A chargedcapacitor provides constant DC link voltage. A 3.125 MVAalternator coupled to diesel engine and governor is used as source[2].The synchronous machine voltage and speed outputs are used asfeedback inputs to a Simulink Control system that contains theDiesel engine and governor block as well as an excitation systemblock.

3. Operating Principle:

The output voltage of D-STATCOM is generated by a DC - ACvoltage source inverter operated from an energy storage capacitor.From the DC input voltage source, provided by a charged capacitor,the converter produces a set of controllable three phase outputvoltages with the frequency of AC power system. Each outputvoltage is in phase with and coupled to the corresponding ACvoltage via tie reactance(leakage reactance of couplingtransformer). By varying the magnitude of output voltage produced,the reactive power exchange between D-STATCOM and AC systemis controlled. If the amplitude of output voltage is increased (ordecreased) above the AC system voltage, the converter generates (orabsorbs) reactive power for the AC system[2]. D-STATCOM acts as ashunt compensator connected in parallel to the system so that it caninject the necessary compensation currents

4. Voltage Fluctuation Problem On Ac Bus

In non-islanded mode of operation, in absence of STATCOM, local excessive reactive power demand issupplied by the utility grid. Sudden transients in the reactivepower demand are taken care of by utility grid and the ACbus voltage is maintained. However, in islanded mode ofoperation, in absence of STATCOM, reactive power demandis completely supplied by the converters of the power sourcessuch as wind power plants, solar plants and the conventionalsynchronous generators of the pico-hydro plants. With limitedcapability to supply the reactive power demand, islandedAC-bus of microgrid shows drastic fluctuations in the voltage.This provokes need of AC-bus voltage regulating controlsystem to be embedded in STATCOM.

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5. Practical Implementation

The implemented inverter (fig. 1) is a two level voltagesource inverter made by using IGBTs (FGA25N120NTD).IGBTs are driven using a gate driver circuit. The driver circuitdrives the high side IGBTs using separate power suppliesobtained from different transformers for each leg. It alsoconsists of optocouplersfoisolation.Gatingpulses(SPWM)generated from amicrocontrollerareprovidedtoIGBTsthrough the driver circuit. Inverter circuit is connected to Grid through LCL filter. This inverter forms the power circuit ofthe STATCOM as the dc source is replaced withacapacitorofappropriaterating.Fortheimplemented prototype of500VAR, the capacitor is choosen to be 3300uF, at 700V DC.

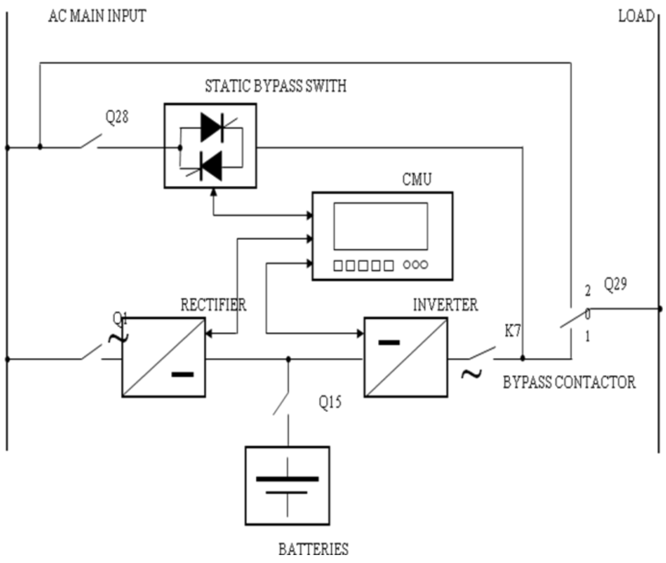

Figure 1: Practically implemented inverter

fig 2 explains the synchronizing control system of STATCOM,DC capacitor voltage control system and Reactivepower control system. Control system is implemented byusing multiple microcontrollers interfaced with personal computervia USART communication interface. In the fig 8microcontroller designated as uC4 is used to generate clockand microcontroller designated as uC1 is used to generate SPWM of required frequency (dictated by the clock givenby microcontroller-uC4.)[3]. Microcontroller designated as uC3is used to detect the frequency of the grid which doneby zero crossing detection logic. Frequency control loop isprogrammed in a software on personal computer whose outputis sent to microcontroller-uc4. Modulation index and Delta(δ) of SPWM can be controlled by giving commands from PC viaUSART communication to microcontroller 1 (uC1). For bothdelta(δ) and modulation index control, PID controller logic is embedded in the STATCOM control terminal on computer. Forboth delta(δ) and modulation index control, PID controllerlogic is embedded in the software.

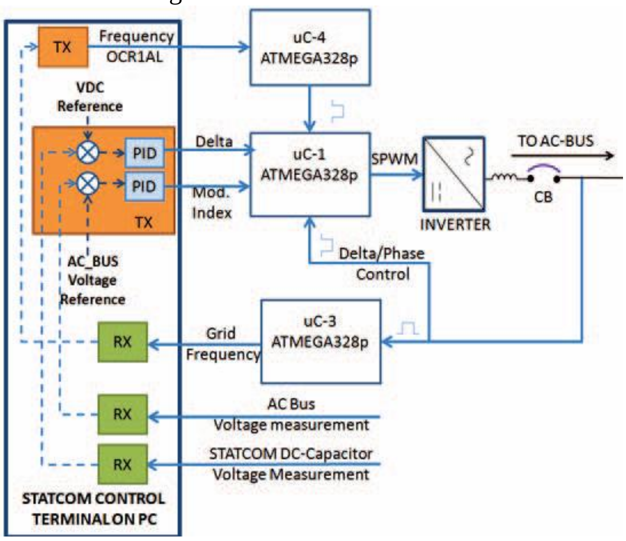

Figure 2: STATCOM control system schematic

6. Modelling Of D-Statcom

Fig.3 shows complete model of D-STATCOM along with controlcircuit. The power circuit as well as control system are modeledusing PSB and simulink. The synchronous generator is showndriven by a diesel engine set. Three phase AC loads are connected atthe other end of alternator[4]. A step down transformer is connected tostep down the generatedvoltage415Vdistributionlevel.DSTATCOMconsists of PWM voltage source inverter circuit and aDC capacitor connected at one end. IGBT based PWM inverter isimplemented using Universal bridge blockfromPowerElectronicssubsetofPSB.RCsnubbercircuits are connected in parallel witheach IGBT for protection

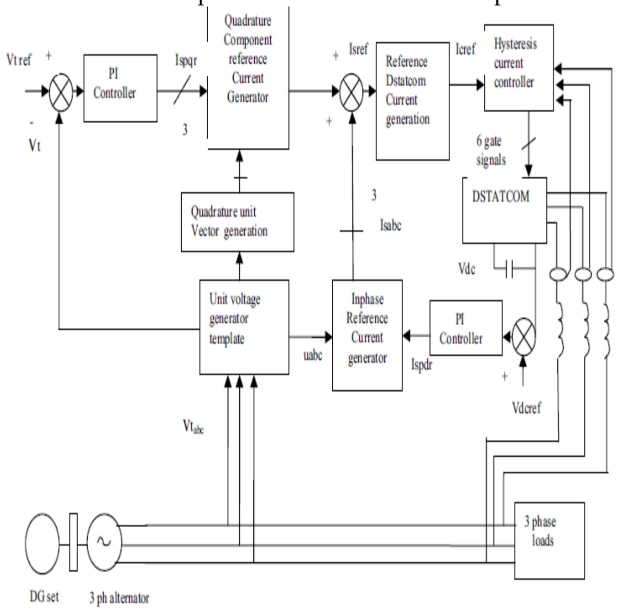

Figure 3: Control scheme of D-STATCOM for Isolated AlternatorSystem driven by Diesel Engine

A salient pole 3.125MVA, 4 pole, 60 Hz, three phase synchronousmachine is modeled as an isolated alternator having L-L rms voltageof 2.4kV. The associated diesel engine and governor models areselected from standard synchronousmachine voltage regulator combined to an exciter is used. A 3MVA, 2.4kV/ 415 V ph-ph rms. voltagestep-down transformer is used with the primary winding connectedin delta and secondary winding in star connected to ground.The load on the system is modeled using the block three phaseparallel RL load connected in star configuration with the neutralconnected to ground. Active power (P), Reactive power (Ql) hasbeen set to 1MW and 0.8Mvar. Capacitive reactive power has beenset to zero. Provision is made to connect two such loads in parallelso that the effect of sudden load addition and removal is studiedeasily. The feeder connected from the generator to load is modeledusing appropriate R, Lcomponents. control circuit of D-STATCOM with two PIcontrollers. One PI controller is to regulate the DC link voltagewhile the second PI controller is to regulate the terminal voltage atpoint of common coupling (PCC). The in-phase components of DSTATCOMreference currents are responsible for the case of powerfactor correction of load and the quadrature components of supplyreference currents are to regulate the AC system voltage at PCC[4].

The output of PI controller over the DC bus voltageis considered asthe amplitude of the in-phase component of supply referencecurrents and the output of PI controller over AC terminal isconsidered as the amplitude of the quadrature component of supplyreference currents. The instantaneous reference currents are obtainedby multiplying the in-phase supply reference current with unitvectors and quadrature supply reference currents with quadratureunit vectors. Once the reference currents for D-STATCOM aregenerated, a carrier less PWM controller is employed over thesensed D-STATCOM currents and instantaneous reference currents.If the current in phase 'A' is less than reference current in thatphase, then upper IGBT for leg 'a' is 'OFF' and lower IGBT is'ON'. Similar logic is applied to other two legs. The controllercontrols the D-STATCOM currents in a band around the desiredreference current values. The hysteresis controller generates
appropriate switching pulses for six IGBTs of the VSI inverter.

8. Conclusion

A detailed model of D-STATCOM for an isolated system consistingof a three-phase alternator driven by Diesel engine and feeding localloads has been developed. The simulation of the physical model isdone in MATLAB environment using Simulink and PSB. Theresponses show that D-STATCOM is able to achieve power factorcorrection, voltage regulation and load balancing. It is hoped that theproposed D-STATCOM will be quite useful in a number ofapplications like isolated power generation for ships, aircrafts.

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