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Study of a State-of-the Art M-STATCOM

Ehsan ahmadi [1], shariatmadar seyed Mohhamad [2], reza ahad [3],

[1] naragh Branch, Islamic Azad University, naragh, IRAN
Beheshti Street, delejanCity, markazi, Iran
dr.abolfazl.zahedi@gmail.com
[2] Nargh branch, Islamic Azad University, Naragh, IRAN
shariatmadar@iau-naragh.ac.ir
[3] naragh Branch, Islamic Azad University, naragh, IRAN
sadr Street, shahin shahr City, esfahan, Iran
reza_ahad1@yahoo.com

Abstract: This paper presents a novel static synchronouscompensator based on the state-of-the-art modular multilevelconverter called M-STATCOM. In order to support the DC busvoltage, maintain the stability of DC-link capacitor voltage,obtain an output voltage with low harmonic content andcompensate reactive power under unbalanced load operation, adirect current control (DCC) technique is used. For highaccuracy and good control system response, Level-Shift SinePulse Width Modulation (LS-PWM) technique is selected. TheM-STATCOM is simulated in PSCAD/EMTDC (version 4.5.1)environment and its static and dynamic responses are discussed.The effectiveness and feasibility of the proposed modulation andcontrol strategy is validated by the simulation results.

Keywords: M-STATCOM, DCbus voltage, direct currentcontrol technique , Level-Shift Sine Pulse WidthModulation,static and dynamic responses.

1. Introduction:

Industry loads cause increasing power quality problems tothe utility grids. Amongst many compensation techniques, thestatic synchronous compensator (STATCOM) is found as afeasible solution to provide precise and flexible control tomitigate disturbances and effectively improve the powerqualityThe multilevel converter based STATCOM caneasily reach up to medium or high-voltagehigh-powerapplications without transformers, which make the wholesystem heavy and bulky. The most commonly used multilevel converters inSTATCOMs applications are: Neutral Point Clamped (NPC),the Flying Capacitor (FC), Cascade H-Bridge (CHB) andModular Multilevel Converters (MMC). The first threetopologies have been widely studied in the technicalliterature, where important issues as control and modulatingstrategies have been already addressed Also, someothers emerging multilevel topologiescan be also used asSTATCOMs, such as the Cascade H-Bridge based on CurrentSource Inverters (CHB-CSI) Moreover, someasymmetrical approaches can be proposed for the CHBtopology in order to obtain higher number of levels, wheredifferent DC voltages in the H-Bridges are used Even though, all the aforementioned multilevel topologiesare well suited for STATCOM applications, according to thelatest researches the MMC can be considered as thenext-generation of multilevelconverters due to its operatingperformance. In fact, the modulation, losses andsemiconductor requirements are deeply examined in.MMC provides a viable approach to construct a reliable andcost effective STATCOM (called M-STATCOM) withincreased number of levels, capable of eliminating interfacetransformers and replace them by inexpensive reactors toallow active and reactive power exchange with the powersystem. The active powerredistributed in the internal loopscan be used for negativesequence balancing purpose Therefore, M-STATCOM can work continuously under threephaseunbalance conditions, capable of overcomesymmetrical and asymmetrical faults without increasing therisk of a system collapse and furthermore it has intrinsic faultmanagement capability.The rest of the paper is organized as follows: the topologyof M-STATCOM is explained in section II. Then, escribes the Level-ShiftSinePulseWidthModulation (LSPWM)technique as well as the direct current control scheme;in section IV M-STATCOM is simulated in PSCAD/EMTDC environment and its static and dynamic responses are discussed. Finally, section V concluded out the paper.

2.Topology of M-Statcom

Fig. 1 shows the topology structure of a three phase MMC.In the converter, each phase consists of two legs that arenamed as positive leg and negative leg, respectively. In

Corresponding Author: ehsan, ahmadi, *dr.abolfazl.zahedi@gmail.com*, 09189654635

thiswork, each leg contains 50 identical, evenly and seriallyconnected sub-modules (SMs) along with an inductor *l* (thatlimits the fault current). Each sub-module consist of a floatingdc capacitor *C* and two insulated-gate bipolar transistors (T1and T2) that form a bi-directional chopper As shown in, the voltage of each capacitor is *Vd*/*N*,where *Vd* is the DC bus voltage and *N* is the number of submodulesin each leg. In a sub-module, when the upper switchis on (and the lower switch is off), *C* is inserted in the circuit,in which the state of the sub-module is defined “on” or “1”;when the upper switch is off (and the lower switch is on), *C* is
by-passed, here the sub-module is “off” or “0’. Then, bycontrolling the states of these sub-modules, the levels in thelegs can be changed. Therefore, the terminal voltage of eachsub-module can be either its capacitor voltage or zero,depending on the switching states as shown in TABLE I.

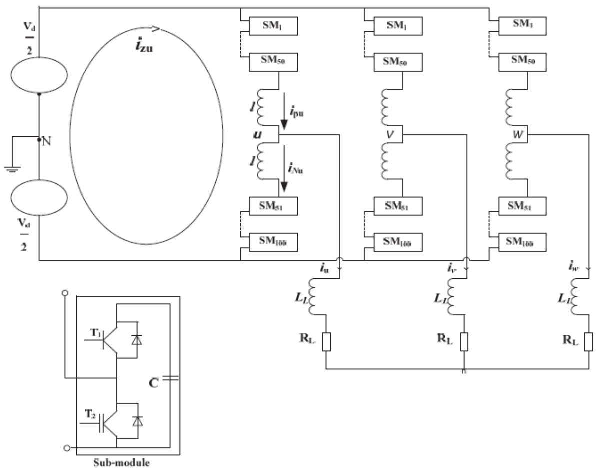

Figure 1: thestructure of three phasem statcomalong withsub module

difference between voltages of the positive and negative legsand the load current. Hence, in this example there are a totalof five levelsthatcorresponds to 2*N*+1; then for 50 submodules,there will be 101 levels.

3. Modulation Technique Anddirect Current Control Strategy

The MMC modulation technique has a significant impacton the output voltage, harmonics, switching losses andcapacitors’ voltage balancing. Multi-carrier based PWMscheme is a common modulation method for multi-levelconverters and it is quite suitable for the proposed topology.Multi-carrier modulation technique uses a reference ormodulating signal (usually sinusoidal) which is comparedwith several carrier signals (usually triangular waves).For high accuracy and good control system response, LSPWM
technique is selected as the modulation strategy. Ituses two reversed sine waves to be compared with severaltriangular waves that has the same amplitude and phase, butthey are vertical shifted level by level, which allows theconverter to work in two different modes that will beexplained in the following.
The converter has two operating modes which are namedbasic-level mode that operates only with *N* basic levels andfull-level mode that operates with not only basic levels butalso inserted levels (the total number of levels is 2*N*+1),respectively. In the basic-level mode, at any time, the numberof “on” sub-modules in the phase is equal to *N*, and there is
none level upon the inductors. On the other hand, in the fulllevelmode, when the converter operates with inserted levelstates, the number of “on” sub-modules is not equal to *N*, and

Table I: Switching states of the Sub-Module

Mode	T1	T2	State
1	1	0	ON
2	0	1	OFF
3	0	0	BLOCK

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.

5. Design of Statcom.

The PCB of Power Circuit is shown in (fig. 1). PCB wasmade using EAGLE Software.Power circuit contains the main topology of DC-AC conversion.
The power circuit consists of three parallel legs, each
leg consisting of two IGBTs(FGA25N120NTD) which areswitched using the switching pulses obtained from the drivercircuit.

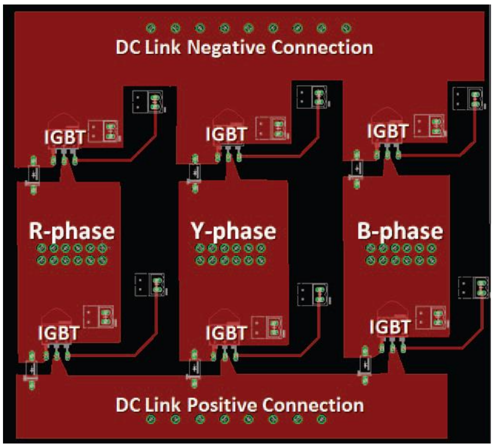

Figure 2: PCB layout of power circuit

A Driver circuit is interfaced with the power circuit toensure required driving characteristics of the IGBTs. TheIGBTs are switched at a frequency of 2kHz. This leads toproblem of high voltage spikes across the switch due to circuitinductance and also it leads to ringing. To eliminate this, RCsnubber circuit is used in the STATCOM circuit. When theswitch gets open, circuit eliminates the voltage transients andringing , as it provides alternate path for the current flowingthrough circuit's intrinsic leakage inductanceAlso itdissipates the energy in resistor and thus junction temperatureis reduced.

6. Practical Implementation

The implemented inverter (fig. 3) 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.

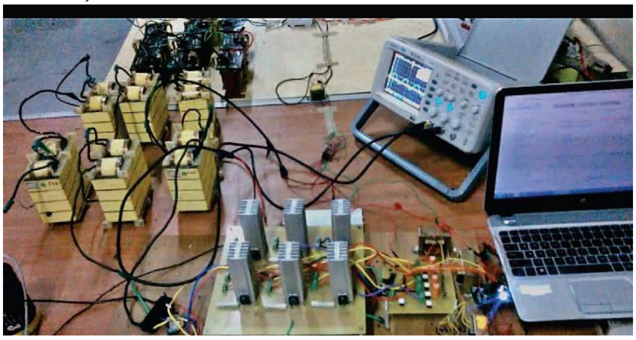

Figure 3: Practically implemented inverter

fig 4 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.). 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.

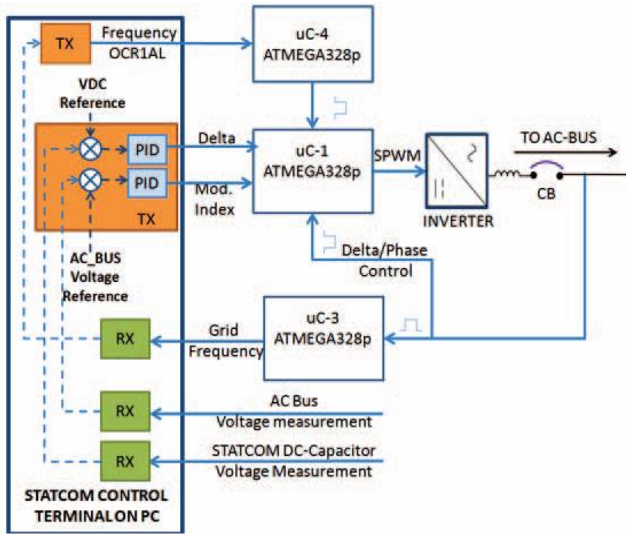

Figure 4: STATCOM control system schematic

7. Results

Response Of DC Voltage Regulating Control System With Sudden Change In The Reactive Power Demand On Acbus, Capacitor Voltage On The DC Link Of The Statcomtends To Decrease Drastically.Losses In The Power Circuitare Increased Due To Increased Reactive Power Output Ofstatcom. To Cope Up With The Increased Losses The Deltaof STATCOM Is Made More Lagging By The Regulating Pidcontrol System. Fig 7 Shows The Response Of The Control System. Capacitor Voltage Experiences A Droop In The Start Butis Observed To Return Back To The Reference Value. From Thecontrol Effort, It Can Be Seen That The Delta Has Settled To Agreater Lagging Value.Response Of AC Bus Voltage Regulating/ Reactive Powercontrol Systewith Sudden Islanding Or Sudden Increase In The Reactivepower Demand In Islanded Operation, Leads To Sudden Droop Inthe AC Bus Voltages. (Fig 6) Reactive Power Control System

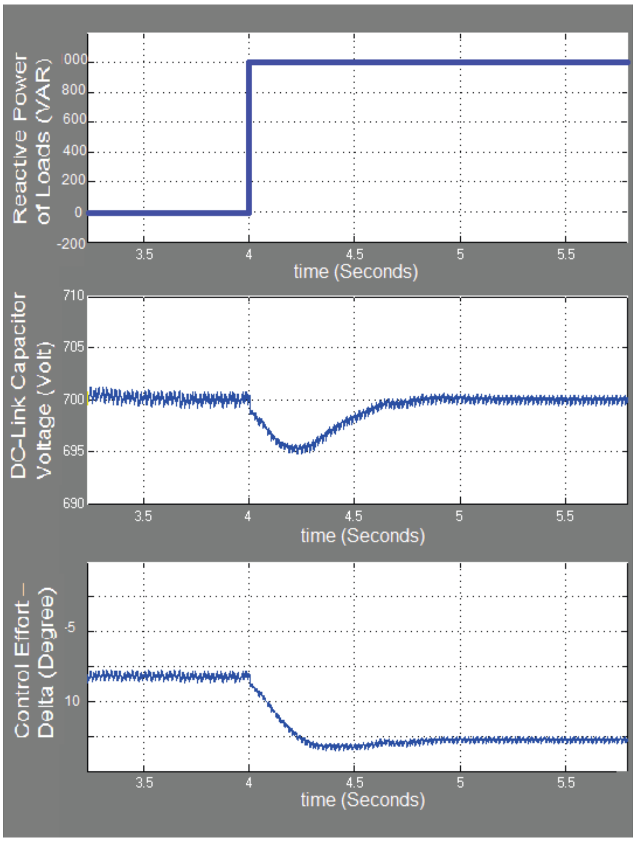

Figure 5: Response of dc voltage regulating control system basedon change in reactive power demand

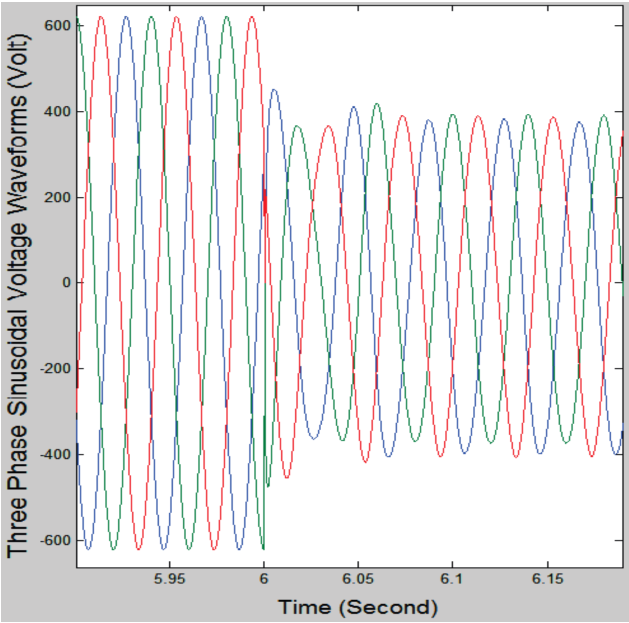

Figure 6: Response of AC bus voltage without STATCOM

8. Conclusion

This paper discusses application of STATCOM in a microgrid with islanding scheme. STATCOM is designedfor the reactive power compensation of microgrid and ACbus voltage regulation. STATCOM is simulated along withthe microgrid in MATLAB to observe and improve transientresponse of thcontrols to dynamic loading and islandinscenarios. Designed control strategy respondstoACbusvoltagefluctuations and configures STATCOM to throwdynamic reactive power accordingly. During sudden excessivereactive power demand, inspite of presence ofcontrolstrategy,
capacitor DC link voltage shows significant voltage droopbefore settling to thereferencevalueThisdictates need fora better control strategy.

References:

[1] Pillay, K.; Dahidah,.A. Mariun, N.B.,2010. On comparing theperformance of voltage source converters based D-STATCOM forvoltage sag mitigation. pp:432-437.
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[2] Mohammadi, H.P. Bina, M.T.,2011. "A Transformerless Medium-VoltageSTATCOM Topology Based on Extended Modular MultilevelConverters," *Power Electronics, IEEE Transactions on* . pp:1534-1545.

[3] Simon iwnicki, 2006. Handbook of railway vechicle dynamics, gauge of the rollers.crc press pubilshers.pp:446-484.

[4] Acha E. 2013.A New STATCOM Model for Power Flows Using theNewton–Raphson Method Power Systems [J]. IEEE Transactions onPower Electronics,pp: 2455 – 2465.

Author Profile

Ehsan ahmadi was born delijan, Iran, in 1991. He received his B.Sc. Degree in Electric Power Engineering from Islamic Azad Univercity Branch of golpaygan in 2014. Currently, he is studying his M.Sc. Degree in Electric Power Engineering frorm Islamic Azad Univercity Branch of naragh, Iran.

Seyed Mohammad Shariatmadar: was born in Qom, Iran on August 1973. He received B*Sc*., and *MSc* and PhD degrees from the Tehran University, Tehran, Iran in 1996, the South Tehran Branch, Azad University in 2003 And Science and Research Branch, Islamic Azad University Tehran, Iran in2012 respectively. At present, his interests include modeling, analysis and control of electrical machines and electrical machines fault diagnosis, power electronic drives and nonlinear phenomena in power electronics systems.

Reza ahad: was born in esfahan, Iran, in 1991. He received his B.Sc. Degree in Electric Power Engineering from Islamic Azad University Branch of Save, tiran, Currently, he is studying his M.Sc. Degree in Electric Power Engineering frorm Islamic Azad Univercity Branch of naragh, Iran.