A Novel STATCOM Based on Flying Capacitor Modular Multilevel Converter

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Abstract—

A new static synchronous compensator (STATCOM) based on Flying Capacitor modular multilevel converter (DCM2C) is proposed in this thesis. In this converter topology the capacitor voltage is clamped by using a low power rating diode in each sub-module (SM). The quantity of voltage sensors is significantly reduced and is free from the number of voltage levels. Furthermore the voltage balancing control method becomes very simple and the capacitor voltage balance speed is fast. Based on the structure of MMC the DCM2C-STATCOM has the capability of Var compensation and negative sequence current compensation. The topology characteristics and compensation control method of DCM2C-STATCOM are investigated in this thesis. That the capacitor voltage of the proposed DCM2C-STATCOM can be well balanced and the Var and negative-sequence current compensation are effective.

Keywords—Modular multilevel converter (MMC), Diode clamped modular multilevel converter (DCM2), static synchronous compensator (STATCOM), flying capacitor and Inverter

I. INTRODUCTION

The development of science and technology is quickly in the electrical industry today is in improving power quality. This is due to the variety of equipment requiring electrical power source with good quality. Equipments such as computer, relay, PLC (programmable logic controller), electric motor drives, etc., Exceptionally touchy changes in voltage are caused by an aggravation in the others in the framework [1,2]. The requirement for electrical vitality stockpiling touchy burdens fueled by uninterruptible power supply (UPS) will require a substantial cost.DVR can be actualized to make turn out to be more financially savvy. A voltage plunge (voltage hangs) is one factor causing diminished electricity, yet this isn't conceivable to keep away from since the season of the unsettling influence can't be known with assurance [3].

Therefore be anticipated event of voltage dips on the side of the source, voltage will not cause disruption on the load side. One way to anticipate it is to use dynamic voltage restorer (DVR). The research conducted was to resolve problems with the voltage dips using a DVR. The occurrence of voltage dips can be different depending on the location of the source disorders and types of disorders. This causes occurrence of differences in analysis methods control to control the DVR. The measure of voltage drop and term incorporated into the classification of voltage plunges is 0.1 up to 0.9 for every unit (pu) for 0.5 cycle to 1minutes in light of the IEEE 1195 1995 standard. This makes the controller the DVR can function admirably at time interims extremely short.DVR Control strategy manufactured neural system controller Narma-L2 demonstrated change without voltage plunges the transient voltage spikes. Plan calculation for dynamic control voltage restorer (DVR) is proposed by utilizing manufactured neural system (ANN) counter spread (CP), on the grounds that with this strategy to play out the emphasis procedure, preparing and reaction speedier [4,5].

II. LITERATURE SURVEY

Power Quality issues envelop an extensive variety of aggravations, for example, voltage lists/swells, flash, music bending, drive transient, and interferences. Voltage hangs can happen at any moment of time, with amplitudes running from 10 – 90% and a term going on for a large portion of a cycle to one moment [6].

Voltage swell, then again, is characterized as an expansion in rms voltage or current at the power recurrence for length from 0.5 cycles to 1 min. typical magnitudes are between 1.1 and 1.8 up. Swell magnitude is also described by its remaining voltage, in this case, always greater than 1.0. Voltage swell are not as important as voltage sags because they are less common in distribution systems [7,8]. Voltage sag and swell can make delicate hardware come up short, or shutdown, and in addition make an extensive current unbalance that could blow circuits or outing breakers. These impacts can be exceptionally broad for the client, extending from minor quality varieties to creation downtime and hardware harm. There are various strategies to moderate voltage hangs and swell, yet the utilization of custom power gadget is thought to be the most proficient technique. Switching off a large inductive load or energizing a large capacitor bank is a typical system event that causes swells. This thesis introduces Dynamic Voltage Restorer and its operating principal. Then, a sample control based on dqo method is used to compensate voltage sags/swell. At the end, MATLAB/SIMULINK model based simulated results were presented to validate the effectiveness of the proposed control method of DVR.

III. FLYING CAPACITOR

The capacitor used as the charge pump is typically known as the flying capacitor another way to explain the operation of a charge pump is to consider it as the combination of a DC to AC converter (The switches) followed by a "Voltage multiplier". The significant goals are to build the limit usage of dissemination feeders (by limiting the rms estimations of the line streams for a predefined control request), lessen the misfortunes and enhance influence quality at the heap transport. The significant presumption was to disregard the varieties in the source voltages. This basically suggests the flow of the source voltage is much slower than the heap elements. At the point when the quick varieties in the source voltage can't be disregarded, these can influence the execution of basic loads, for example, (a) semiconductor creation plants (b) venture factories (c) sustenance preparing plants and (d) car gathering plants. The most widely recognized aggravations in the source voltages are the voltage droops or swells that can be because of (I) unsettling influences emerging in the transmission framework, (ii) neighboring feeder flaws and (iii) circuit or breaker operation. Voltage droops of even 10% going on for 5-10 cycles can bring about expensive harm in basic burdens. The voltage droops can emerge because of symmetrical or unsymmetrical shortcomings. In the last case, negative and zero grouping parts are likewise present. Uncompensated nonlinear loads in the conveyance framework can cause consonant segments in the supply voltages. To relieve the issues caused by low quality of energy supply, arrangement associated compensators are utilized [9].

These are called as Dynamic Voltage Restorer (DVR) in the literature as their primary application is to compensate for voltage sags and swells. Their configuration is similar to that of SSSC. However, the control techniques are different. Also, a DVR is expected to respond fast (less than 1/4 cycle) and thus employs PWM converters using IGBT or IGCT devices. The first DVR entered commercial service on the Duke Power System in U.S.A. in August 1996. It has a rating of 2 MVA with 660 kJ of energy storage and is capable of compensating 50% voltage sag for a period of 0.5 second (30 cycles). It was installed to protect a highly automated yarn manufacturing and rug weaving facility. Since then, several DVRs have been installed to protect microprocessor fabrication plants, project mills etc. Typically, DVRs are made of modular design with a module rating of 2 MVA or 5 MVA. They have been installed in substations of voltage rating from 11 kV to 69 kV. A DVR has to supply energy to the load during the voltage sags. If a DVR has to supply active power over longer periods, it is convenient to provide a shunt converter that is connected to the DVR on the DC side. As a matter of fact one could envisage a combination of DSTATCOM and DVR connected on the DC side to compensate for both load and supply voltage variations. In this section, we discuss the application of DVR for fundamental frequency voltage source converter is typically one or more converters connected in series to provide the required voltage rating [10].

The DVR can inject a (fundamental frequency) voltage in each phase of required magnitude and phase. The DVR has two operating modes:

(i) Standby (also termed as short circuit operation (SCO) mode) where the voltage injected has zero magnitude.
(ii) Boost (when the DVR injects a required voltage of appropriate magnitude and phase to restore the pre fault load bus voltage).

IV. POWER QUALITY PROBLEMS

A power quality problem is defined as "an occurrence manifested in voltage, current, or frequency deviations, which results in failure or disoperation of end-use equipment". Commercial customers have become more exacting in their demand for relative 'quality' of power they purchase, variations in flow or voltage can actually damage and disrupt sensitive electronics, computers, and microprocessors. As modern society relies more heavily on high tech-processes, power quality has become even more critical. Power quality is influenced among other factors by utility operations, customer load types, and equipment designs.

Customers, along with their engineering equipment manufacturers and vendors, generate, propagate, and receive power quality problems. Electrical disturbances can ensue from problems within the customer's facility, even though the supply voltage is constant. Achieving power quality demands a united effort between the utility and the customer. Customers and utilities have a shared responsibility in the mitigation of voltage variation. Mitigation of the effects on consumer devices from voltage variations can be achieved only if utilities work with manufacturers in the design of consumer products so that the products function during normal utility operation.

Power quality can be evaluated by its effect on the performance of the equipment. Weather conditions and other factors may preclude utilities from providing power at constant voltage and constant frequency. The primary sorts of voltage unsettling influences that happen in electrical power dispersion frameworks incorporate the accompanying; Transients, Voltage lists, Voltage swells, Interruptions, Distortion, Flicker, Noise, Frequency deviations. These voltage unsettling influences will cause different power quality issues like electrical hardware harm, glitch of PC and other touchy gear. Power Quality problems need to be addressed in a coordinated manner since a large number of variables are involved. The different players in the power quality arena are: Distribution utilities, Commercial customers, Residential customers, Industrial customer, Equipment manufacturers, and Health care facilities.

V. SERIES CONTROLEER (DVR)

A. Principle and Operation

The primary capacity of a DVR is the assurance of touchy burdens from voltage droops/swells originating from the system. Along these lines as appeared in Figure the DVR is situated on approach of delicate burdens. On the off chance that a blame happens on different lines, DVR embeds arrangement voltage VDVR and repays stack voltage to pre blame esteem. The flitting amplitudes of the three infused stage voltages are controlled, for example, to wipe out any hindering impacts of transport blame to the heap voltage VL. This implies any differential voltages caused by transient unsettling influences in the air conditioner feeder will be repaid by a comparable voltage produced by the converter and infused on the medium voltage level through the promoter transformer. The DVR works freely of the kind of blame or any occasion that occurs in the framework, gave that the entire framework stays associated with the supply matrix, i.e. the line breaker does not trip. For most down to earth cases, a more conservative outline can be accomplished by just remunerating the positive and negative grouping parts of the voltage unsettling influence seen at the contribution of the DVR. This choice is Reasonable in light of the fact that for a commonplace conveyance transport arrangement, the zero succession part of unsettling influence won't go through the progression down transformer as a result of endless impedance for this segment.

B. Control Method

The essential elements of a controller in a DVR are the recognition of voltage list/swell occasions in the framework; calculation of the adjusting voltage, age of trigger heartbeats to the sinusoidal PWM based DC-AC inverter, revision of any peculiarities in the arrangement voltage infusion and end of the trigger heartbeats when the occasion has passed. The controller may likewise be utilized to move the DC-AC inverter into rectifier mode to charge the capacitors in the DC vitality interface without voltage aggravations.

The dqo transformation or Park's transformation is used to control of DVR. The dqo method gives the sag depth and phase shift information with start and end times. The quantities are expressed as the instantaneous space vectors. Firstly convert the voltage from abc reference frame to d-q-o reference. For simplicity zero phase sequence components is ignored. The detection is carried outing each of the three phases. The control scheme for the proposed system is based on the comparison of a voltage reference and the measured terminal voltage (Va,Vb,Vc).The voltage sags is detected when the supply drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The mistake flag is utilized as a balance flag that permits producing a replacement design for the power switches (IGBT's) constituting the voltage source converter. The substitution design is produced by methods for the sinusoidal heartbeat width tweak strategy (SPWM); voltages are controlled through the adjustment.

VI. NEURAL NETWORKS

Neural control is a branch of the general field of intelligent control, which is based on the concept of artificial intelligence (AI). AI can be defined as computer emulation of the human thinking process. The AI techniques are generally classified as expert systems (ES), fuzzy logic (FL) and artificial neural networks (ANN). The classical expert systems are based on Boolean algebra and use precise calculations while fuzzy logic systems involve calculations based on an approximate reasoning. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth–truth values between 'completely true' and 'completely false'. It was introduced by Dr Lotfi Zadeh of UC/Berkeley in the 1960s as a means to model the uncertainty of natural language. Reality of a sensible articulation in fluffy rationale is a number in the interim [0,1]. Fluffy rationale has risen as a productive device for the control of complex modern procedures and frameworks. It is utilized for forms that have no straightforward numerical model, for exceedingly non-direct procedures, or where the handling of phonetically detailed information is to be performed. Despite the fact that it was concocted in the United States, the fast development of this innovation began from Japan and has now again achieved the USA and Europe. The controllers in view of this scientific approach are known as fluffy controllers.

The utilization of counterfeit neural systems (ANNs) is the most capable approach in AI. ANNs are data preparing structures which copy the design and operational method of the natural sensory tissue. Any ANN is a framework made up of a few essential elements (named neurones) which are interconnected and work in parallel transmitting signs to each other keeping in mind the end goal to accomplish a specific preparing assignment. A standout amongst the most exceptional highlights of ANNs is their capacity to reproduce the learning procedure. They are provided with sets of information and yield signals from which general standards are naturally inferred so that the ANN will be (in specific conditions) equipped for producing the right yield for a flag that was not already utilized. The neural approach can be joined with the fluffy rationale creating neuro-fuzzy frameworks that consolidate the benefits of the two control ideal models.

VII. BLOCKS USED IN THE CIRCUIT

C. Universal Bridge

The Universal Bridge block implements a universal three-phase power converter that consists of up to six power switches connected in a bridge configuration. The type of power switch and converter configuration is selectable from the dialog box.The Universal Bridge block allows simulation of converters using both naturally commutated (and line-commutated) power electronic devices (diodes or thyristors) and forced-commutated devices (GTO, IGBT, and MOSFET).The Universal Bridge block is the basic block for building two-level voltage-sourced converters (VSC).

D. Discrete 3 Phase PLL

A phase-locked loop (PLL) is a circuit that is capable of synchronizing an output signal generated by an oscillator with a reference or input signal in frequency as well as in phase. A PLL is a closed loop frequency control system that operates on the phased sensitive detection of phase difference between two signals, the reference signal and a feedback signal. A phase-locked loop is used to set a frequency in such a manner that it matches a reference frequency produced by a reference oscillator.

Phase-locked loop (PLL) integrated circuits produce an oscillator frequency output which matches an input frequency signal. A typical PLL may include a phase-frequency detector, a charge pump, and a voltage-controlled oscillator (VCO). A phase locked loop circuit operates by producing an oscillator frequency to match the frequency of an input signal. The phase frequency detector compares an input or system clock with an output clock and provides clock control signals to the charge pump. Phase Locked Loop (PLL) circuits may be used for frequency control. Many applications require phase-locked loop (PLL) circuits which will work with high frequencies.

E. Discrete PWM Generator

The output pulses are a vector (with values=0 or 1). Depending on the selected "Generator Mode", the output vector contains: For a 1-arm bridge: Two pulses. Pulse 1 is for the upper switch and pulse 2 is for the lower switch. For a 2-arm bridge: Four pulses. Pulses 1 and 3 are respectively for the upper switches of the first and second arm. Pulses 2 and 4 are for the lower switches. For a 3-arm bridge: Six pulses. Pulses 1,3 and 5 are respectively for the upper switches of the first, second and third arm. Pulses 2,4 and 6 are for the lower switches.

For double 3-arm bridges: Twelve pulses. The first six pulses (pulses 1 to 6) must be sent to the first 3-arm bridge and the last six (pulses 7 to 12) to the second 3-arm bridge. By selecting "Internal generation" you can control the modulation index m, frequency and phase of the output voltage from the internal parameters (m, Freq and Phase). Otherwise, external signals are used for pulse generation. The width of the input vector must be 1 for single phase bridges (1-arm or 2-arm) and 3 for 3-phase bridges (single or double bridge).

F. Filter Circuit

Three-phase harmonics channels are shunt components that are utilized as a part of energy frameworks for diminishing voltage twisting and for control factor adjustment. Nonlinear components, for example, control electronic converters create consonant streams or harmonics voltages, which are infused into control framework. The subsequent twisted streams moving through framework impedance create harmonics voltage bending. harmonics channels lessen mutilation by redirecting consonant streams in low impedance ways. harmonics channels are intended to be capacitive at crucial frequency, so they are additionally utilized for creating responsive power required by converters and for control factor amendment.

VIII. SIMULATION RESULTS

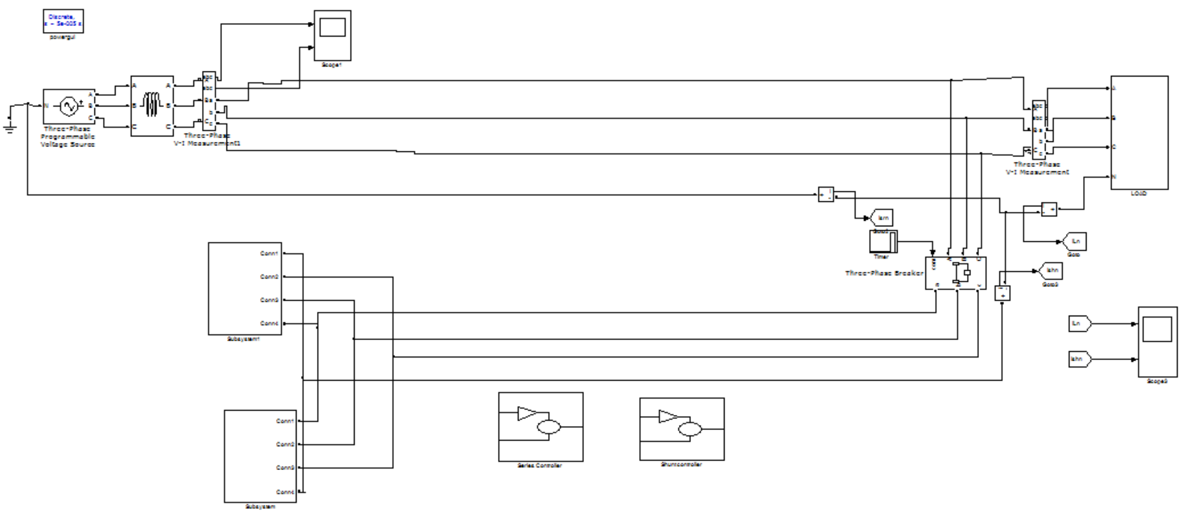

Fig.1 Simulink model of Voltage regulation

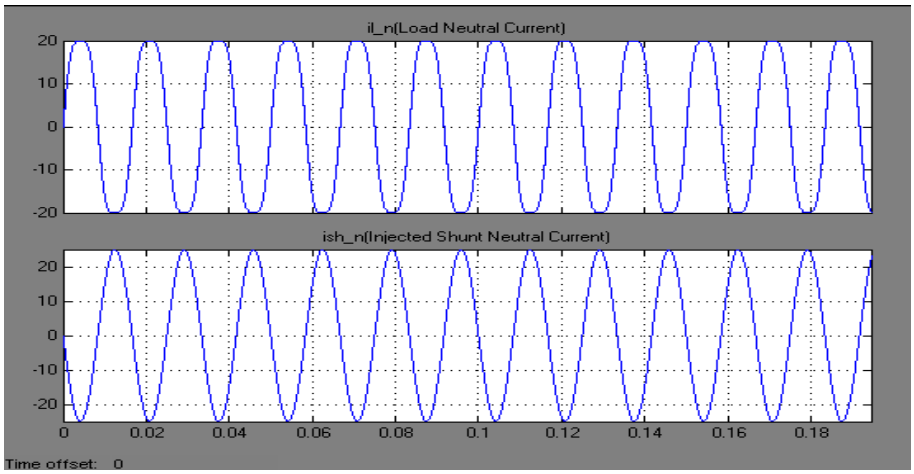

Fig 2. Injecting Voltage wavforms

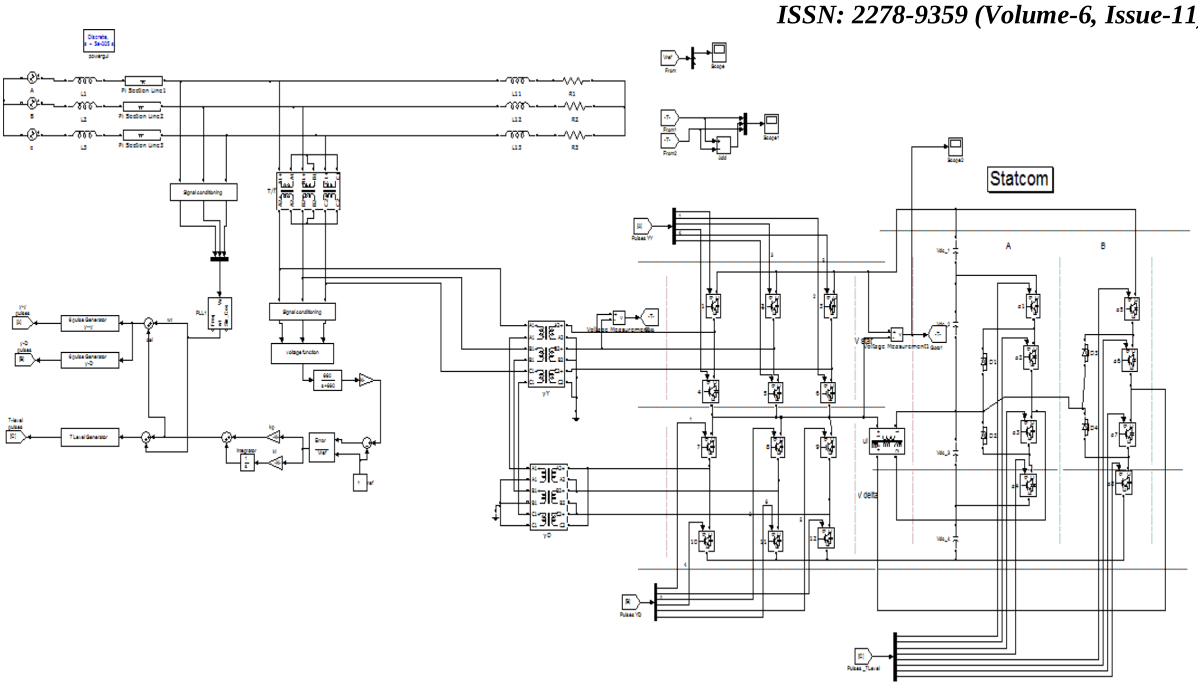

Fig.3 Simulink model of Proposed Method

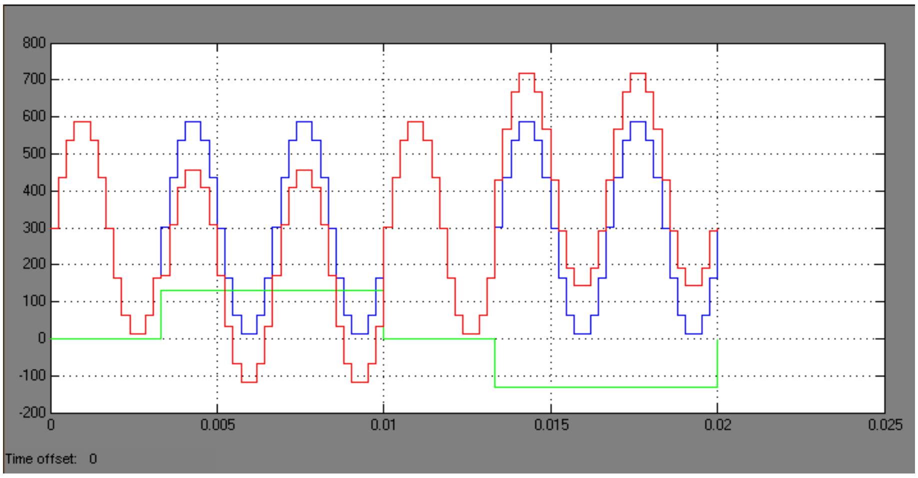

Fig.4 Simulation results of the Inverter

IX. CONCLUSION

This paper presents a DCM2C-STATCOM system. Based on the traditional MMC topology, the proposed DCM2C utilizing cinching diodes to keep the SM capacitor voltages adjusted. The fundamental favorable position of this topology is that the amount of capacitor voltage sensors is essentially decreased and the adjusting control technique is exceptionally basic. Moreover the capacitor voltage adjust speed is quick. Albeit additional bracing diodes and inductors are required in the novel topology than that of the conventional MMC, the present rating of the diodes and inductors is much lower than the present rating of the primary power branch of the converter. So the cost of DCM2C isn't substantially higher than that of the conventional MMC.With the proposed power control strategy, the DCM2C-STATCOM system can realize VAR compensation and negative-sequence current compensation. Simulation results improve the effectiveness of DCM2C topology along with the proposed power control strategy.

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