

MLI-DSTATCOM Integrated With Distribution Transformer for Power Quality Enhancement in PDS

T.Rakesh¹, Dr.V. Madhusudhan², Dr.M.Sushama³

Research Scholar, JNTUH, Kukatpally, Hyderabad.

Principal & Dean, KORMCE, Kadapa.

Professor, JNTUCEH, Kukatpally, Hyderabad.

Email: raki242@gmail.com

Abstract: - This article offers a novel cascaded structure convertor (CMC)-primarily based mostly distribution-kind STATCOM integrated with distribution electrical device for medium voltage utility. The star-related, n-level CMC is connected to the winding faucets on the first windings of the electrical device to reap voltage strain discount and maintain a bendy affiliation voltage degree. Taking complete use of the spare potential of distribution electrical device, a compromise between cascaded cells depends and also the voltage pressure is completed. The CMC-based altogether DSTATCOM is controlled as a controlled current supply to inject compensation current to the first windings through the taps. A modified decoupled fashionable manipulate is planned to control the device. Simulation version and scale-down model area unit developed to verify the performance of the planned integrated structure. Simulation and experimental effects demonstrate the great performance of the planned structure for reactive power compensation.

Keywords—cascaded multilevel converter; DSTATCOM; reactive power compensation; winding taps; distribution transformer, Power Distribution Systems (PDS).

1 INTRODUCTION

With the event of energetic distribution community, there are still no pleasant solutions of dynamic reactive strength compensation for medium voltage (MV) distribution network. The prevailing solutions are high voltage thyristor switched capacitors (HVTSC), thyristor controlled reactor (TCR), magnetic-voltage governable reactor (MCR), and excessive voltage static synchronous compensator (STATCOM) [1]. Among those solutions, speedy showing STATCOM could be a promising era being significantly used as a result of the fashionable dynamic shunt compensator for reactive electricity compensation and harmonic elimination in distribution system {2-3}. the prevailing distribution-type STATCOM (DSTATCOM) is hooked up to the MV distribution network (10-kV/35-kV in China) either directly or through a decrease, semicustom coupling electrical device thanks to the high voltage pressure. DSTATCOM

prepared with a transformer makes the complete gizmo cumbersome and serious [4]. Consequently, transformer-much less DSTATCOM turns into a lot of and a lot of appealing currently.

To put off the coupling electrical device and reduce the load and amount of the entire system, cascaded construction convertor (CMC)-based all transformers-less STATCOM is developed in {5-7}. Several single-phase full-bridge (FB) cells in assortment are designed to dam the high voltage thanks to the preventative voltage obstacles of mate less switch device (which embrace IGBT). However, the amount of cells in assortment is usually bigger than 10 for every section in MV distribution community whereas the value-powerful 1.7-kV IGBTs are chosen as a result of the switch devices, that makes it bigger powerful to style the manipulate system and music the parameters. After all we tend to are ready to choose high voltage switch gadgets to minimize the cascaded count that embrace three.3kV or 4.5kV IGBTs, but those high voltage IGBTs are too luxurious and now not perpetually offered within the markets.

One of the possible answers to cut back the desired voltage rating of the voltage provide convertor (VSC) could be a combination of passive and active components to create a mate less tool. These gadgets are observed as hybrid STATCOMs (HSTATCOMs). Typically, capacitors or TCRs are delivered in assortment to the VSC to minimize the voltage strain, thanks to the actual fact most of the fall happens at the capacitors {8-10}. This type of topology reduces the rating of the dc link voltage and is suitable for business packages. However, the coordination manages of passive associated energetic components are a thorn. Influenced by the form of autotransformer and considering the spare capability of gift distribution electrical device, this paper proposes a novel CMC-primarily based mostly STATCOM integrated with distribution electrical device. The megastar connected, n-level STATCOM is hooked up to the taps on the first windings of the distribution electrical device. The faucets of the three-segment windings are distinctive designed to stay a large voltage vary for the association of DSTATCOM. The discount of voltage strain is

useful to decrease the amount of H-bridge cells. The compensation currents are injected through the taps to amass reactive electricity compensation and harmonic removal. The planned structure takes full advantage of the spare capability of the distribution electrical device and achieves a compromise among the voltage stress and also the amount of cells asynchronous.

This paper is organized as follows. The device configuration and dealing mechanism are conferred in section II. The management device is advanced in section III. The simulation and experimental tests are offered in phase IV. Conclusions are drawn in part V.

SYASTEM CONFIGUTATION

A. DSTATCOM Integrated with Distribution Transformer

Fig.1(a) shows the topology of the projected CMC-based altogether DSTATCOM incorporated with distribution electrical device. The link sort of the distribution electrical device is Dyn11. There are a set of taps at the first windings, which may be labeled as A3, B3 and C3. The particularly designed taps are used for compensation currents injection that is pretty specific from the standard association patterns (the relationship factors are either A-B-C or a-b-c.). The symbols are as follows: u_{Ti} and u_i ($i=A, B, C$) are the faucets voltage and electrical converter output voltage, R and L are the resistance and inductance of the reactor. The star connected CMC-primarily based mostly DSTATCOM consists of many single section complete bridges nonparallel in step with cluster. Supposed that the association issue voltage (continually named because the PCC) is lipoprotein, the height price of the voltage for star connected cells in every section to cope with could also be calculated as:

$$V_p = \frac{V_{l-l}}{\sqrt{3}} \times \sqrt{2} = 0.816V_{l-l}. \quad (1)$$

If the voltage of the PCC is 10-kV, it is 8.16-kV. When the 1.7-kV IGBTs are chosen to style the H-bridge convertor cells, the dc link voltage is designed around 1100V in line with the book of facts. To extend the dc voltage utilization magnitude relation, the modulation index is ready to 0.928. Then the cascaded range N is calculated via:

$$N = \frac{V_p}{1100 \times 0.928} = 8. \quad (2)$$

Now we elect the winding faucets because the affiliation purpose rather than the standard PCC, the voltage rating of the DSTATCOM may be reduced. If the central faucets square measure chosen for the affiliation of DSTATCOM (as shown in Fig.1(a)), the

affiliation voltage is half the PCC, i.e. 5-kV. Therefore, the cascaded cells asynchronous may be reduced by [$*fr1$]. Central faucets don't seem to be the sole alternative for the affiliation of DSTATCOM. Fig.1 (b) shows a five-winding faucets structure. Taking phase-A as associate example, the 5 faucets square measure labeled as A1 to A5. The faucets don't seem to be equally spaced however they're utterly axisymmetric concerning the point A3. The look will make sure the voltage is symmetrical, i.e. $|AA1|=|A5X|$ $|AA2|=|A4X|$ and $|AA3|=|A3X|$. As mentioned on top of, one may opt for alternative cluster of faucets because the affiliation points for DSTATCOM to realize a versatile voltage vary. In Fig. 1 (b), each faucets cluster labeled A5, B5 and C5 or cluster A2, B2, and C2 may be chosen because the affiliation purpose for DSTATCOM and that they square measure drawn in red dash lines and blue dash lines, severally. The nearer the faucet is to the point, the smaller the affiliation purpose voltage for DSTATCOM.

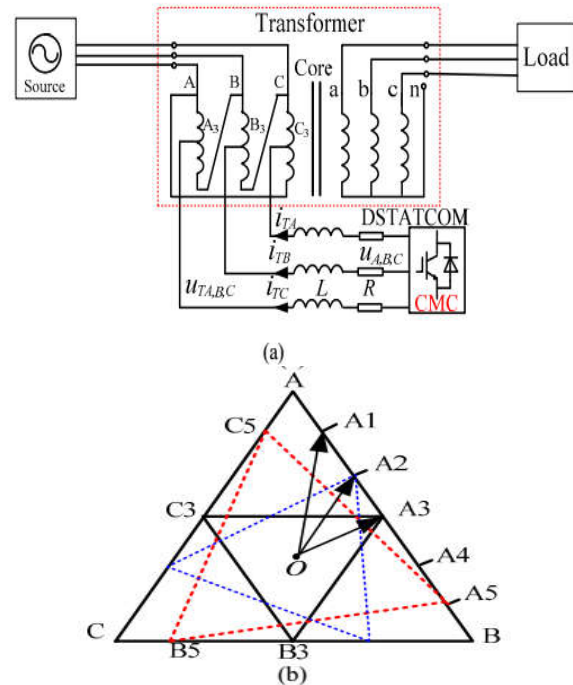


Fig. 1: CMC-based STATCOM integrated with the existing distribution transformer: (a) three phase circuit diagram; (b) different connection types

One could concern that whether or not the present distribution electrical device are going to be full, as a result of the compensation currents square measure injected through the winding faucets. In fact, the typical load magnitude relation of the distribution electrical device is often below 0.3. Solely the spare capability of the distribution electrical device is employed for reactive power compensation. Moreover, the particular compensation capability is strictly restricted to forestall the electrical device from overloading.

B. Working Mechanism of the Integrated System

The compensation currents square measure injected through the faucets, as shown in Fig.2. The CMC-based DSTATCOM is controlled as a manageable current supply during this paper. Fig.2 shows one part diagram of the integrated system. The core of the distribution electrical device is happy by the supply current i_s , compensation current i_c and cargo current i_L along. Generator driver (MMF) balance relationship and power balance principle is accustomed make a case for the operating mechanism. The flux generated by the injection current (red broken lines) and therefore the corresponding reactive and harmonic elements of the load current (blue broken lines) is balanced.

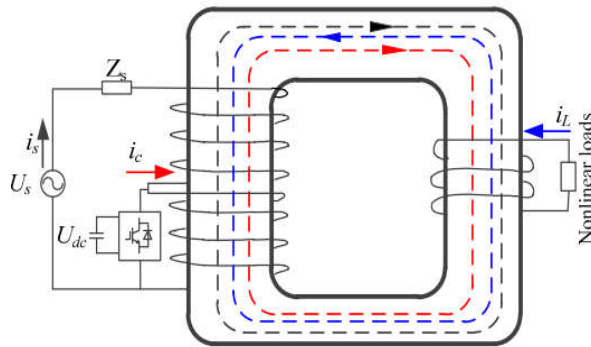


Fig. 2: Single phase circuit diagram of the integration system

Form the purpose of power-balancing theorem, if the reactive power generated/absorbed by the DSTATCOM is up to that of the load needed, whole reactive power compensation will be achieved.

III CONTROL STRATEGY

Fig.4 shows the management diagram of the integrated DSTATCOM system. The entire management in the main consists of the subsequent blocks:

- 1) Reference signal conversion block, that is meant to convert the reactive current signals from the secondary facet to the injection purpose (winding faucets of the first side);
- 2) Decoupled current management, as shown in Fig. 3;
- 3) Voltage reconciliation management, together with each individual reconciliation management between the cascaded device cells in every cluster and cluster reconciliation management between the 3 clusters.

A. Current Command for the Inner Loop

The system detects the load voltages and currents to extract the reactive current elements and generates the reference signals. In contrast to typical DSTATCOM, the measure purpose and injection purpose don't seem to be identical purpose. Moreover, the electrical device has totally different completely different} affiliation

varieties and therefore the point of the voltage and current at either side is also different. Therefore, it's necessary to convert the signals measured at the load facet to the winding faucets (at the grid side). The reactive current part i_{qT} will be born-again by:

$$i_{qT} = \frac{i_{qt}}{(U_T / U_2)} \quad (3)$$

Where U_T is that the voltage of the faucets, U_2 is that the voltage of the secondary facet, and i_{qT} is that the injection element at the winding faucets. Parenthetically, if the central faucets square measure chosen to attach the DSTATCOM, U_T/U_2 is half the quantitative relation of electrical device. a tiny low correction Δi_q is superimposed to i_{qT} to compensate the reactive power loss of the electrical device and it are often designed as ten to fifteen of the rated current. The phase variations are often resolved by applying 2 three-phase digital phase-locked-loops (PLLs).

B. Decoupled Current Control

The inner decoupled current management regulates instant active and reactive power by considering a group of 3 clusters as a 3 part device [4]. The output voltages area unit determined by the proportional and integral controller from the deviations between the command currents i_{dref} , i_{qref} and also the actual injection currents i_{Td} , i_{Tq} . The voltage of the injection purpose and voltage across the ac electrical device L area unit side to the within the feed forward manner, as shown in Fig. 3.

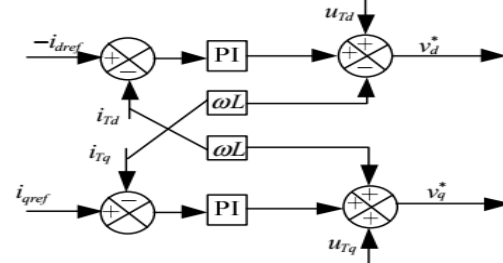


Fig. 3 Decoupled current control

C. Voltage Balancing Control

For CMC-based DSTATCOM, it's essential to balance the dc electrical condenser voltage of the cells in every cluster. Heaps of management ways are planned to realize voltage leveling management. Among these solutions, class-conscious electrical condenser voltage leveling controllers area unit enticing. during this paper, the management ways conferred in [4] and [5] area unit applied to realize individual leveling management and cluster leveling management, as shown in Fig. 4. The calculation of the typical voltages values and also the style of the parameters of the controllers don't seem to be the main focus of this paper, thus we can't waver it here.

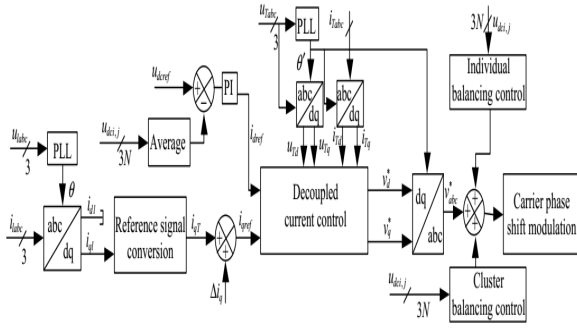


Fig. 4: Control diagram of the system

IV SIMULATION RESULTS

A. Simulation Results

To verify the viability of the planned structure, a simulation has been enforced in MATLAB/Simulink. Three single-phase multi-winding electrical devices with faucets provided by SymPowerSystem tool case square measure won't to model the Dyn11 transformer shown in Fig.1 (a). The key parameters square measure listed in Tab. 1. For simplicity, we elect the central faucets because the affiliation purpose for STATCOM to verify its performance. At first, the load is ready to 200-kW and 200-kVar (inductive). Fig.5 shows the three-phase voltages and currents of the grid facet. At $t=0.2s$, DSTATCOM is place into operation. When concerning 0.5 the elemental amount (For 50Hz system, it's ten ms), the DSTATCOM generate reactive power to keep up unity power issue of the grid facet. The dynamic response is thus quick.

TABLE I. Parameters of the Simulation System

Parameters	Symbol	Values
System Voltage	U_s	10.5KV
Line Frequency	f	50Hz
Rated Capacity of the Transformer	S_N	1MVA
Ratio of the Transformer	k	10kV/380V
Nominal DC-Link Voltage	V_{dc}	1500V
Cascaded Cell Number	N	4
DC Bus Capacitor	C_{dc}	6000 μ F
PWM Carrier Frequency	f_{car}	2kHz
AC Filter Inductor	L	16mH

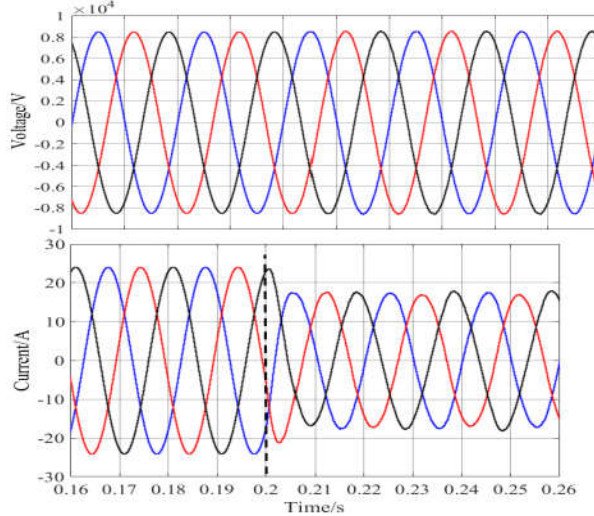


Fig. 5 Grid voltages (Phase to ground) and currents before and after compensation (inductive)

To more verify the dynamic performance of the planned integrated DSTATCOM underneath fast load modification condition, the electrical phenomenon reactive load is inflated with a step of 100- kVar (capacitive) at $t=0.3s$, 0.4s and 0.5s (the electrical device switch simulation at the secondary side). At $t=0.6s$, a 100kVar (inductive) load is connected to the load bus. Fig.6 shows the phase-A voltage (phase to ground) and current of the grid facet. Fig.7 shows the output average power of the DSTATCOM. At $t=0.2s$, DSTATCOM is place into operation. Once fast load modification happens, the voltage and current of the grid facet are perpetually in-phase, i.e. solely active power is transferred although the ac lines. The reactive power consumption by the load and electrical device is provided by the DSTATCOM. In Section III, a little correction Δiq is accessorial to iqT to compensate the reactive power value of the electrical device. Fig.8 shows the impact of the correction on the facility issue (PF) of the grid facet. Fig. 9 shows voltage (phase-to-phase) and current of the integrated structure: (a) Before compensation; (b) after compensation.

If the correction is removed, the PF will solely be inflated to 0.95, as a result of solely the load currents are detected to come up with the reference current. Once the correction is hooked up, the PF is inflated to one.

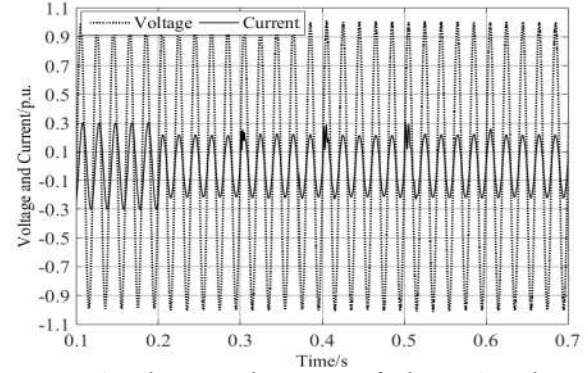


Fig. 6 Voltage and current of Phase-A with a sudden load change

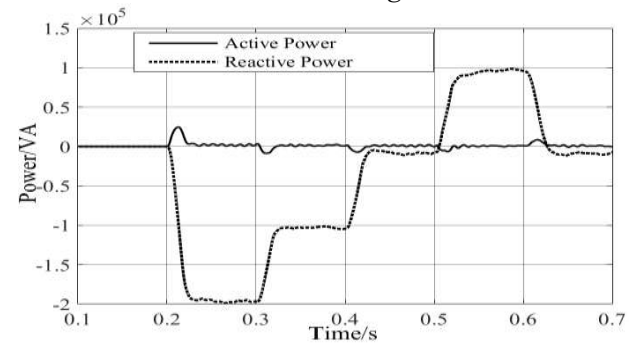


Fig. 7 Output average power of the DSTATCOM (converter absorbing real power= $P(+)$, converter absorbing reactive= $Q(+)$)

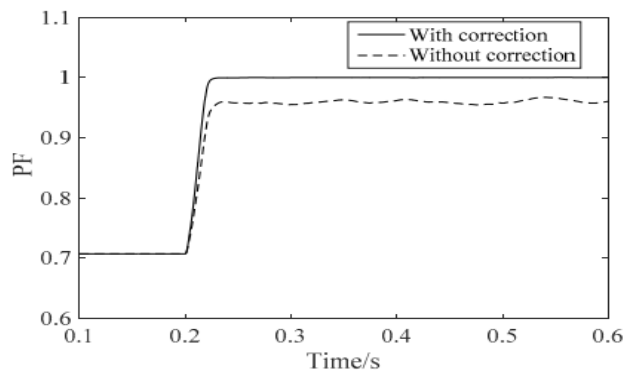


Fig. 8 Effects of the correction Δi_q on the power factor of grid side

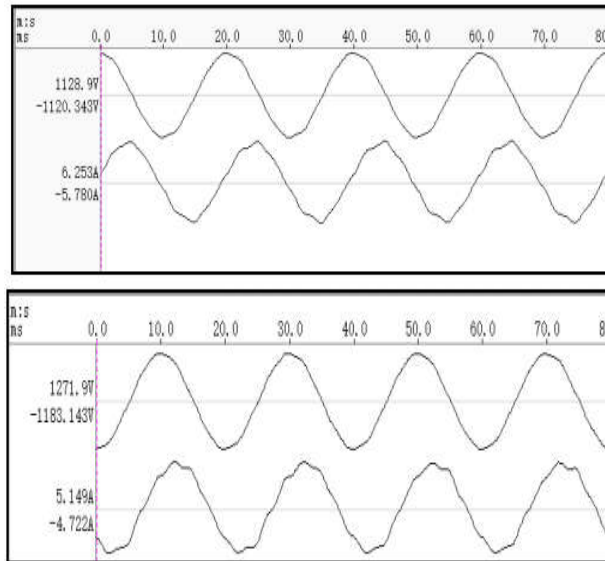


Fig. 9: Voltage (phase-to-phase) and current of the integrated structure: (a) Before compensation; (b) after compensation.

V CONCLUSION

A novel CMC-based DSTATCOM integrated with distribution electrical device is projected during this paper. The DSTATCOM is connected to the faucets on the first windings and therefore the compensation currents area unit injected through the faucets to compensate the reactive power of load the distribution electrical device. The voltage stress for DSTATCOM is shriveled, that is useful to attain a compromise between the amount of cells nonparallel and therefore the association voltage. A changed current management strategy is additionally designed for the integrated structure. Each simulation and down-scale paradigm experimental system area unit developed to verify the effectiveness of the projected integrated structure. The take a look at results show that the projected structure has smart performance for reactive power compensation.

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Authors



Rakesh Teerdala is receive BTech in Electrical Engineering and MTech in Electrical Power Systems from JNTUH, Hyderabad. He is PhD Scholar in Dept. of Electrical & Electronics Engg, JNTUH Hyderabad; presently he is working in the field of Power Quality in Distribution Systems. His area of interest in Power Distribution Systems Modeling, Power Quality, Power System Reliability Analysis.



Dr. V. Madhusudhan, *M.Tech, Ph.D* took the charge as principal since June 2013. He did his Ph.D in Electrical Engineering. His area of interests are power system engineering; Reliability Engineering etc. **Dr. V. Madhusudhan** has published around 30 technical papers in national/international journals and conferences. He guided around 20 M.Tech projects and presently 5 students are pursuing Ph.D under his guidance. He is life member of professional bodies like ISTE, IE(I), NAFEN, SSI. He acted as the member board of studies, for some prestigious universities. He chaired the technical sessions in several national/international conferences. He occupied many prestigious academic and administrative positions such as professor, HOD and principal in a career spanning over 28 years.



Dr. M. Sushama, born on 8th Feb 1973, in Nalgonda , a small town near Nagarjuna Sagar, A.P, India .Obtained her B.Tech degree in 1993 and M.Tech degree in 2003 JNTU, INDIA She obtained her Ph.D. from JNTU Hyderabad, India in 2009 in the area of “Power Quality” using Wavelet Transforms. . She had 20 years of teaching & 10 years of research experience. She has published 20 international conference papers in various IEEE sponsored conferences, 15 International journals and one article in “Electrical INDIA”. Her research interests include Power Quality, Wavelet Transforms, and Neural & Fuzzy expert Systems. She is currently guiding 5 Ph.D students. She is a life member of ISTE, Systems Society of India (SSI) & IETE