VOLTAGE AND CURRENT CONTROL IN A DISTRIBUTION NETWORK USING OPEN LOOP AND CLOSED LOOP OPERATED STATCOM

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Abstract: Electric power systems are among the best achievements of the last century. Today, vital problems, like AN ever-increasing demand, the versatile and reliable integration of distributed generation or a growth in worrisome masses, should be borne in mind. In this context, sensible grids play a key role, permitting higher potency of power systems. Power physics provides solutions to the same matters, since it permits numerous energy sources to be integrated into sensible grids. Withal, the look of the varied control schemes that are necessary for the proper operation of the power-electronic interface is a important issue that has got to continuously be taken into thought. This paper deals with the look of the system of a distribution static synchronous compensator (DSTATCOM) supported flying-capacitor structure converters. The system is tailored to catch up on each voltage sags by suggests that of reactive-power injection and voltage imbalances caused by unbalanced masses. The look of the general management is carried out by exploitation the root-locus and frequency-response techniques, rising each the transient response and therefore the steady-state error of the control system. Simulation results obtained exploitation PSCADTM/EMTDCTM (Manitoba Hydro International Ltd., Commerce Drive, Winnipeg, MB, Canada) show the resultant voltage regulation.

KEYWORDS: power quality; voltage sag; smart grid; distribution static synchronous compensator (DSTATCOM); flying-capacitor multilevel converter

I. Introduction:

Over the past century, power systems are supported the paradigm of enormous power generation. notwithstanding, this paradigm has become obsolete, because of the depletion of standard fuel provides, like oil and coal, the rise of demand, the provision of competitive distributed energy sources integrated into the grid and environmental problems [1]. Microgrids and good grids are the alternatives that contribute toward achieving the rising potential of distributed generation and to obtain a lot of reliable power systems [2].

Microgrids will operate in Associate in Nursing interconnected mode or in Associate in Nursing islanded mode, and need power-electronic converters, because of the character of most of the distributed energy sources [3]. On the opposite hand, a sensible grid should integrate advanced sensing technologies, management ways and communications into the electricity grid. The good grid is anticipated to exhibit the subsequent key characteristics: self-healing, client friendly, attack resistant, power quality improvement, capability to accommodate all generation and storage choices, best plus for markets and economical operation [1].

The key technologies concerned in good grids embody integrated communications across the grid, advanced management schemes, sensing, metering and measure, advanced grid parts and call support and human interfaces. Among these technologies, the evolution of the advanced grid parts is one among the foremost relevant problems, like succeeding generation of power grid devices, that embody flexible AC gear mechanism (FACTS) devices [4].

Static synchronous compensators (STATCOM) and distribution static synchronous compensators (DSTATCOM) are 2 FACTS devices supported a voltage-source device (VSC), that are wide used to improve voltage regulation and harmonic elimination and to balance the grid current [5,6]; they play a key role among the good grid conception. They'll so contribute toward enhancing power quality and getting a a lot of reliable electricity grid.

Although there are several aspects concerned within the style and operation of STATCOM and DSTACOM devices, this paper focuses on 2 explicit issues: the VSC topology and also the style of the system. For low-tension and low-power applications, STATCOMs and DSTACOMs supported two-level VSCs are ordinarily used. Notwithstanding, because the rating of those devices continues to extend within the realm of reactive-power compensation, the facility electronic converters are starting to be higher-voltage points of the grid. during this approach, construction device topologies are at the moment the foremost standard topologies for high voltage applications: they need been advanced as a way to scale back the voltage stress on the switching devices [7] and to boost on the standard of the wave shape with less filtering necessities. A number of construction device topologies are recommend, though the foremost standard are: neutral-point-clamped converters (NPC), flying-capacitor converters (FC) and H-bridge converters [8]. All of them have edges and disadvantages, and varied pulse-width modulation (PWM) techniques are often used to draw on the simplest management characteristics of those converters [9]. though one among the handicaps of FC converters is that the enlarged range of bulk capacitors with the quantity of levels, that is larger than within the case of government agency configurations, the system to balance the voltages of the capacitors is more versatile within the case of the FC topology, because of the next range of switch mixtures than obtained within the case of government agency

topologies [10]. the utilization of FC converters for STATCOM and DSTATCOM applications has antecedently been rumored within the literature: a STATCOM supported Associate in Nursing FC VSC topology

This paper offers with the design of a manage system for a DSTATCOM, which employs a five-level flying-capacitor VSC. The DSTATCOM is tailored to inject up to 100 MVAr and is related to a 13.8 kV distribution grid. The work focuses on the design methodology of the overall manipulate system and uses classical linear manage tools, such as the root-locus and frequency-response techniques, in order to tailor the control scheme. The manage structure employs the synchronous reference body method and implements proportional-integral regulators combined with resonant-type regulators [19]. Unlike other references that plan manage structures for DSTATCOMs, complete records about the design criteria is furnished in this work, such as transient-response specifications, balance margins and the steady-state error. The control gadget is designed to compensate for each balanced voltage sags and voltage imbalances induced by means of unbalanced masses or asymmetrical faults. The injection of reactive power ameliorates the voltage sags, while the voltage imbalance compensation is accomplished by using balancing the grid current.

II. Model of Statcom

The basic configuration of a DSTATCOM is proven in Figure 1: it consists of a VSC, which is connected to the grid by means of means of a coupling transformer. In this paper, a five-level flying-capacitor VSC is used, while a capacitor, C, is used as a DC strength storage system in the VSC. The grid involves an AC voltage collectively with a resistance and a inductive reactance (Rg - Xg), which mannequin the impedance of the line. In addition to the DSTATCOM, a range of loads can additionally be linked to the grid at the point of common coupling (PCC): in the example shown in Figure 1, up to three masses can be connected.

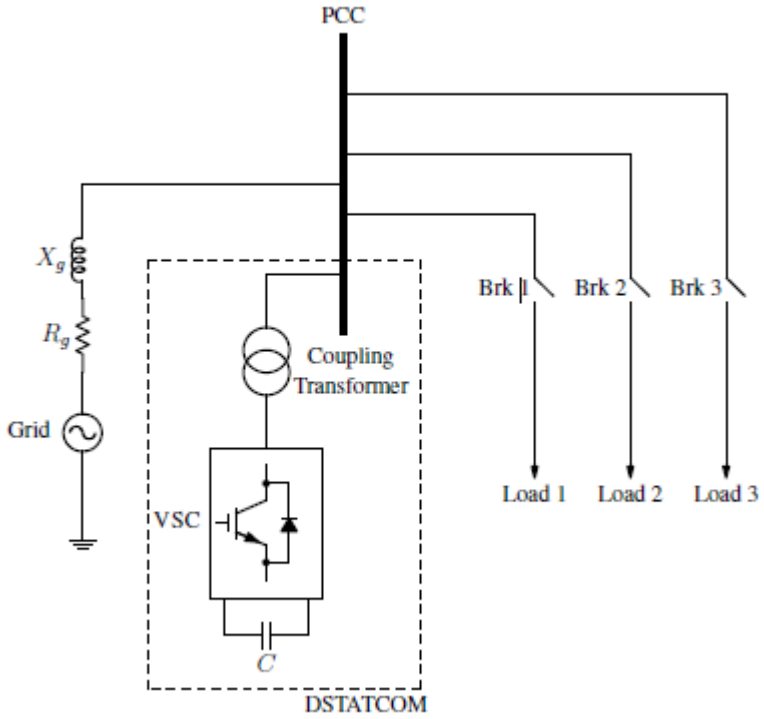

Figure 1. Example of a grid feeding three loads and a distribution static synchronous Compensator (DSTATCOM) connected to the point of common coupling (PCC). Brk, Circuit breaker.

The equivalent circuit of the DSTATCOM connected at the PCC is delineated in Figure a pair of, in which vs is that the grid voltage, v is that the voltage at the PCC and Rg and Lg area unit the resistance and therefore the inductance model line electric resistance. because the VSC are operated by a PWM theme with a high shift frequency, its average model is taken under consideration [20], and {therefore the and also the} VSC has therefore been shapely as a perfect voltage source u; whereas v is that the PCC voltage; i is that the current injected into the grid by the DSTATCOM; Ig is the current of the grid and iL is that the load current. Finally, the coupling electrical device is shapely victimization the resistance, R, and therefore the inductance, L.

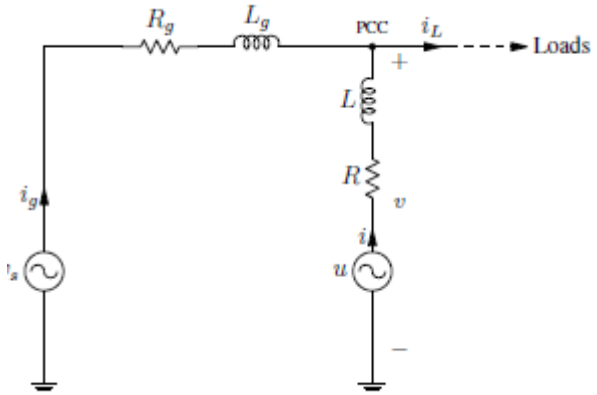

Figure 2. One-line equivalent circuit of the DSTATCOM.

III. Control System Configuration

The main objective of the system is three-fold: to contribute toward maintaining the grid voltage constant by suggests that of either the injection or absorption of reactive power; to eliminate potential imbalances within the grid current, which may cause voltage imbalances at the PCC, and to manage and to stay constant at a sufficient level the voltage within the DC electrical condenser to a correct operation of the DSTATCOM. Figure four depicts the diagram of the most management theme within which all the variables are written in capital letters, since they're expressed in Laplace's domain.

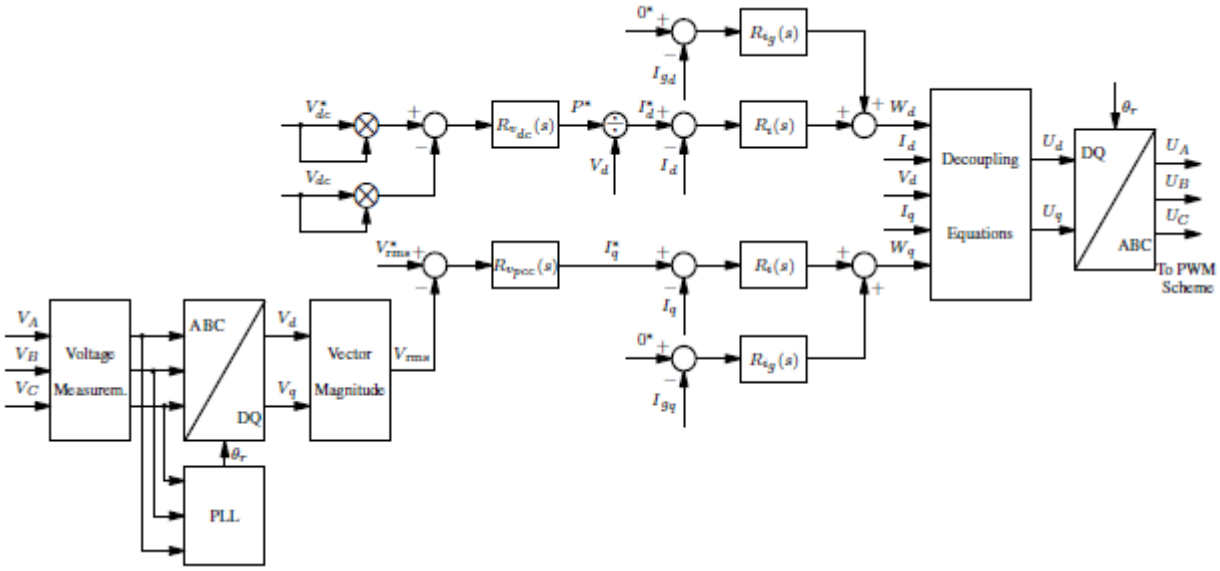

Figure 4. Block diagram of the control system of the DSTATCOM. PLL, phase locked loop.

The superscript asterisk stands for reference values, and also the management structure of every axis (i.e., the d and letter of the alphabet components) is predicated on the employment of 2 nested management loops and a resonant regulator. The control system employs a part fastened loop (PLL) so as to get the angle, r, that is required to carry out the variable transformation within the SRF. The inputs of the PLL area unit the measurements of the grid voltage, that area unit sometimes filtered to eliminate measuring noises. The decoupled Equation (5) is employed to obtain the outputs, Ud(s) and Uq(s), that area unit reworked into the three-phase system variables, UA, UB and UC, by means that of the inverse Park transformation. These variables area unit employed in a curving PWM scheme so as to come up with the firing signals of the FC convertor.

Control of the Voltage in the DC Capacitor

The voltage in the DC capacitor is controlled by means of the current, id, with a configuration of two nested feedback chains. The inner control loop employs the controller, Ri(s), and is tailored to respond much faster than the outer control loop, which uses the regulator, Rvdc(s). As one of the objectives of the overall control system is to achieve zero-tracking error in steady state for step changes in the reference, both regulators use an integral action.

$$Z_d(s) = k_i \frac{I_d^*(s) - I_d(s)}{s} - k_p I_d(s)$$

Control of the Voltage at the PCC

As in the previous control scheme, the control of the PCC voltage also uses a configuration of two nested control loops. In this case, the voltage at the PCC can be modified by controlling the current, iq (i.e., the DSTATCOM absorbs or injects reactive power).

$$Z_q(s) = k_i \frac{I_q^*(s) - I_q(s)}{s} - k_p I_q(s)$$

Control System for Balancing the Grid Current

The antecedently explained management schemes are ready to regulate the voltage at the PCC once operative under balanced conditions (e.g., compensation of balanced voltage sags), as all the variables are transformed into DC quantities within the SRF. The approach during which PI regulators are used so provides a satisfactory result. Even so, unbalanced hundreds and unbalanced short-circuit faults cause current imbalances, that end in voltage imbalances [28]. below these circumstances, and assuming a three-wire three-phase system, the PCC voltage and therefore the grid current can contain positive and negative sequences, that ar reworked within the SRF into a DC part and a second harmonic component, severally.

As the internal model principle (IMP) determines that, so as to get zero following error, a stable closed-loop system should embrace the generating polynomials of the reference input and therefore the disturbance input within the divisor of the open-loop system [29], PI-type regulators won't be ready to deal with the second harmonic part. As an alternate, a resonant-type regulator, which has the generating polynomial of a curved input of frequency 2!1 in its divisor, is so planned.

According to Figure a pair of, the grid current may be written as human gamma globulin = iL □ i. The grid current will so be changed by dominant the DSTATCOM current, because the simplified theme in Figure five shows. As the control objective is to keep up the grid current balanced, the reference price for the second harmonic component of the grid current is zero (Igx(s) = 0).

$$M_x^*(s) = \overbrace{\underbrace{k\frac{1+Ts}{1+fTs}}_{R_{PL}(s)}\underbrace{\frac{s}{s^2+(2\omega_1)^2}}_{R_R(s)}}^{R_{4g}(s)}(I_{g_x}(s)^* - I_{g_x}(s))$$

Simulation Results

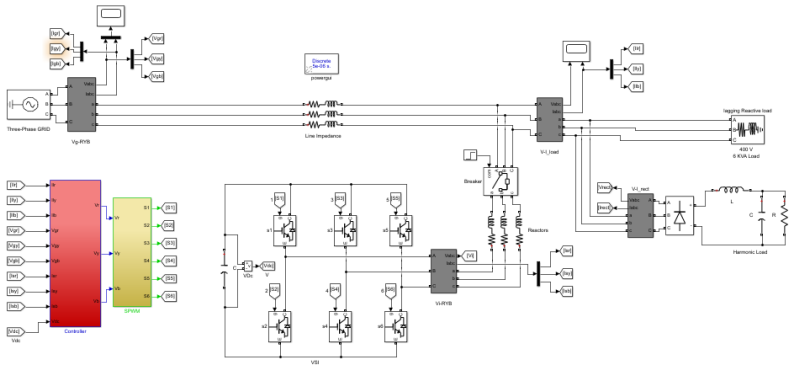

Fig 5: Simulation diagram of proposed distribution system with STATCOM

Figure 5 shows the simulation diagram of distribution system with STATCOM. STATCOM is switched at 0.15 sec. The effect of STATCOM is observed after 0.15 sec in the simulation results fig 6 and fig 7

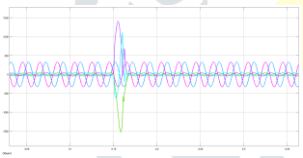

Fig6: Source Voltage and current

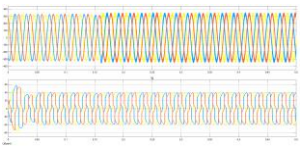

Fig7: Load Voltage and current

Conclusion

This paper has given the look of a bearing system for the operation of a DSTATCOM based mostly on a VSC connected to a distribution grid. The system is customized to compensate for voltage sags and voltage imbalances caused by unbalanced hundreds. The compensation of these voltage imbalances is achieved by equalization the grid current. the system is split into numerous subsystems: the primary one is to blame for dominant the voltage within the DC capacitor; a second system works to control the voltage at the PCC, whereas a 3rd system is used to balance the grid current. Finally, a fourth management theme deals with the equalization of the voltages in the flying capacitors. Basic linear regulators area unit employed in the look, like PI controllers and resonant controllers. the look has been allotted exploitation classical linear management tools, namely, the root-locus and the frequency response techniques, with special attention paid to the factors and specifications of the design. This truth permits one not solely to get a stronger time response of the system, but also to supply a style methodology that may be wont to

add a lot of functionalities to the DSTATCOM, such as compensation or current harmonics by adding numerous resonant controllers in parallel.

References

[1] Ardito, L.; Procaccianti, G.; Menga, G.; Morisio, M. Smart grid technologies in Europe: An overview. Energies 2013, 6, 251–281

[2] M.; Li, X. Design and implementation of a high quality power supply scheme for distributed generation in a micro-grid. Energies 2013, 6, 4924–4944.

[3] Lasseter, R.H. Microgrids. In Proceedings of the IEEE Power Engineering Society Winter Meeting, New York, NY, USA, 27–31 January 2002; Volume 1, pp. 305–308.

[4] Moslehi, K.; Kumar, R. A reliability perspective of the smart grid. IEEE Trans. Smart Grid 2010, 1, 57–64.

[5] Zhang, Y.; Zhang, Y.; Wu, B.; Zhou, J. Power injection model of STATCOM with control and operating limit for power flow and voltage stability analysis. Electr. Power Syst. Res. 2006, 76, 1003–1010

[6] Singh, B.; Jayaprakash, P.; Kumar, S.; Kothari, D.P. Implementation of neural-network-controlled three-leg VSC and a transformer as three-phase four-wire DSTATCOM. IEEE Trans. Ind. Appl. 2011, 47, 1892–1901.

[7] Gupta, R.; Ghosh, A.; Joshi, A. Switching characterization of cascaded multilevel-inverter-controlled systems. IEEE Trans. Ind. Electron. 2008, 55, 1047–1058.

[8] Rodr´ıguez, J.; Lai, J.S.; Peng, F. Multilevel inverters: A survey of topologies, controls, and applications. IEEE Trans. Ind. Electron. 2002, 49, 724–738.

[9] Arrillaga, J.; Liu, Y.H.; Watson, N.R. Flexible Power Transmission. The HVDC Options; Wiley: Chichester, England, UK, 2007.

[10] Feng, C.; Liang, J.; Agelidis, V.G. Modified phase-shifted pwm control for flying capacitor multilevel converters. IEEE Trans. Power Electron. 2007, 22, 178–185.

[11] Shukla, A.; Ghosh, A.; Joshi, A. Static shunt and series compensations of an SMIB system using flying capacitor multilevel inverter. IEEE Trans. Power Deliv. 2005, 20, 2613–2622.

[12] Shukla, A.; Ghosh, A.; Joshi, A. Hysteresis current control operation of flying capacitor multilevel inverter and its application in shunt compensation of distribution systems. IEEE Trans. Power Deliv. 2007, 22, 396–405.

[13] Rao, P.; Crow, M.L.; Yang, Z. STATCOM control for power system voltage control applications. IEEE Trans. Power Deliv. 2000, 15, 1311–1317.

[14] Garc´ıa-Gonz´alez, P.; Garc´ıa-Cerrada, A. Control system for a pwm-based STATCOM. IEEE Trans. Power Deliv. 2000, 15, 1252–1257.

[15] Li, S.; Xu, L.; Haskew, T.A. Control of VSC-based STATCOM using conventional and direct-current vector control strategies. Int. J. Electr. Power Energy Syst. 2013, 45, 175–186.

[16] Shukla, A.; Ghosh, A.; Joshi, A. State feedback control of multilevel inverters for DSTATCOM applications. IEEE Trans. Power Deliv. 2007, 22, 2409–2418.

[17] Mishra, M.K.; Ghosh, A.; Joshi, A. Operation of a DSTATCOM in voltage control mode. EEE Trans. Power Deliv. 2003, 18, 258–264.

[18] Singh, B.; Solanki, J. Comparison of control algorithms for DSTATCOM. IEEE Trans. Ind. Electron. 2009, 56, 2738–2745.

[19] Teodorescu, R.; Blaabjerg, F.; Liserre, M.; Loh, P.C. Proportional-resonant controllers and filters for grid-connected voltage-source converters. IEE Proc. Electr. Power Appl. 2006, 153, 750–762.

[20] Sun, J.; Grotstollen, H. Averaged modeling of switching power converters: Reformulation and theoretical basis. In Proceedings of the 23rd Annual IEEE Power Electronics Specialist Conference (PESC'92), Toledo, Spain, 29 June–3 July 1992; pp. 1165–1172.

[21] Krause, P.C. Analysis of Electric Machinery; McGraw-Hill Inc.: New York, NY, USA, 1986.

[22] Kundur, P. Power System Stability and Control; McGraw-Hill, Inc.: New York, NY, USA, 1994.

[23] Roncero-S´anchez, P.; Feliu-Batlle, V.; Garc´ıa-Cerrada, A. Design and comparison of state-feedback and predictive-integral current controllers for active- and reactive-power control in renewable energy systems. Control Eng. Pract. 2009, 17, 255–266.