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Controlled Structure of HVDC Converter Station by Using Bidirectional VSC with Integrating Smart Grids

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ABSTRACT
This paper presents a new control strategy for over head power transmission i.e using HVDC converter station. In this converter station controlling technique are proposed by using voltage-source converters (VSCs).In this converter rectification and inverter side controlling are consider. In this taking firing angle control of converter switching devices and frequency variation. PWM i.e. pulse width modulation technique is proposed to control conflicts on system. This controller presents high stability margin and fast dc-link voltage regulation, where as it can provide frequency support in the ac side during contingencies. DC-link voltage which e as disintegrations of VSCs interfacing distributed and renewable generation units in to ac systems in the presence of conventional SMs. Frequency and voltage amplitude are adjusted by two separate loops. Short-term deviations in the balance lead to frequency variations and a prolonged mismatch results in blackouts. Operators of power transmission systems are charged with the balancing task, matching the power output of all the generators to the load of their electrical grid. . The load balancing task has become much more challenging as increasingly intermittent and variable generators such as wind turbines and solar cells are added to the grid, forcing other producers to adapt their output much more frequently than has been required in the past. Simulation results are provided to validate the controller effectiveness.

Index Terms: Power control, voltage-source converters (VSCs).

I. INTRODUCTON

Voltage-sourced Converters (VSCs) are six-pulse converters consisting of six power semiconductor switching devices and anti-parallel diodes. From a direct current (DC) voltage source, the VSC generates a set of controllable three-phase output voltages at the frequency of the system voltage. Pulse width modulation is used to control the firing of the semiconductor switching devices, generating an "average" sine wave. Pulse width modulation also helps mitigate the amount of harmonics.

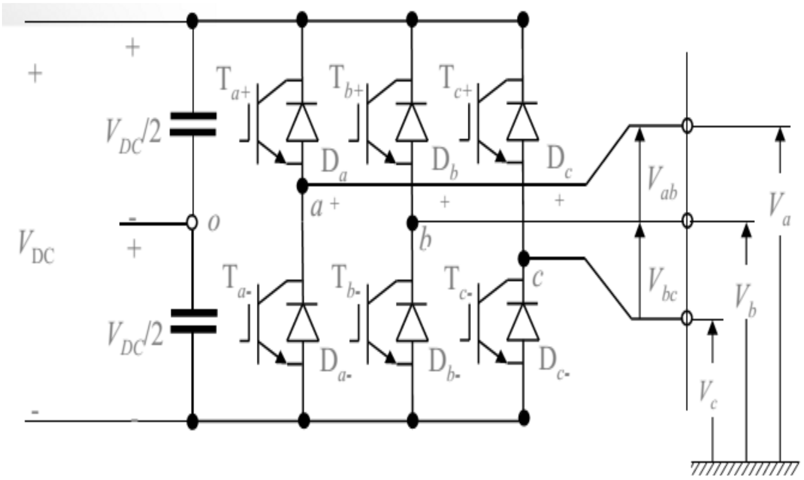


Fig. 1 The topology of a conventional two-level VCS using IGBT switches

In recent years, voltage sourced converter technology has made significant progress through the development and advancement of high power controlled turn-off type semiconductor devices, such as GTOs, IGBTs, and GCTs. Because of the advantages over the line commutated type of converters in performance characteristics and compactness, various applications of the voltage sourced converter based technology have been commissioned. The wide-spread availability of this technology at practical MVA levels was illustrated by numerous references of actual applications.

The word Smart" in Smart Grid is included due to the added benefit of communication and intelligence to the existing power grid which eases the monitoring and maintenance of system. The merit of converting the conventional Power Grid systems to Smart Grid is; more efficient transfer of electricity, quicker restoration of power outages, reduced maintenance and operation cost, increased integration of large scale power source and security control. Smart Grid systems can make an automatic diversion of the power based on the needs and in the case of outages. It also helps to make energy efficient process by creating awareness among customers about the power usage. Significant research has to be done towards stabilizing Smart Grid for the purpose of changing the power grid into an efficient and intelligent electric power distribution system adaptable to the present environment. The benefits of having a Smart Grid rather than having a general Power Grid Systems make a wide difference to both the users and for the organizers of power systems by providing intelligence to the system and reliability to the customers.

According to IEEE smart grid, the entire smart grid system is divided into seven components namely: Bulk generator, Transmission, Distribution, Customer, Service Provider, Operations and Markets. Bulk generation indicates the procedure of handling and gathering power from renewable and non-renewable energy source in huge quantity. Distribution domain delivers the electricity to and from the customers in smart grid. The distribution network connects the savvy meters and all intelligent field devices for managing and controlling them by means of two-way channel. The operations entity of the smart grid model manages and controls the electricity low of all other domains inside the smart grid system. In this process, there are three stages to be passed through before the power reaching the final user, i.e. generation, transmission and distribution. In the first stage the electricity is generated in large generation plants, located in non-populated areas away from loads to get round with the economics of size and environmental issues.

II. PROPOSED CONTROL SYSTEM

For the purpose of analyzing the performance of the designed controllers of the VSC-HVDC system, it is not necessary to represent the studied grid in full detail. Therefore, the connection to PCC at bus-1 and bus-2 are replaced by slack buses with the same short-circuit characteristics as the full detailed grid, see Fig. 2 However, this leads to optimistic results as the in hornet coupling of both PCCs, due to meshed grid topology, is lost. Moreover, the dynamics of the loads and generators is lost in the reduced test model which helps to see the dynamics of the VSC-HVDC clearly. The applied settings of the slack buses and the system parameters are provided. The voltage at the terminals of both network equivalents is set 1 p.u. Because of the DC-link, angle, power exchange between the slack nodes is not dependent on the relative angle between there voltages. Thus the reference angle of both slack buses is set to zero.

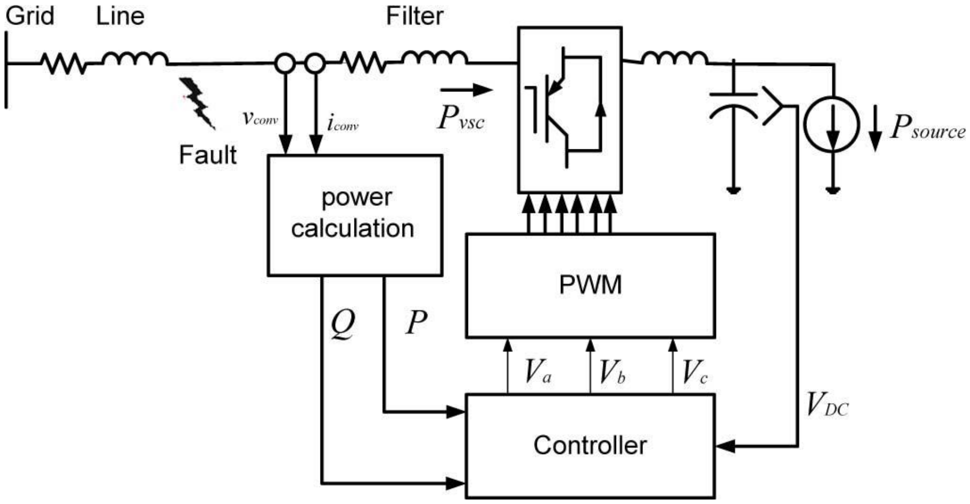


Fig. 2. Schematic view of the simulated system.

As the intent of this paper is the study of the integration of VSC-HVDC to all deviate network constraints in the planning stage, it is as summed that RMS simulations are sufficiently detailed. However, EMT simulations are made for some special study cases.

More over switching actions of the valves are neglected in both EMT and RMS simulations. It has been shown in that this assumption does not result in a considerable loss of accuracy. The choice of outer controllers depends on the application. In order to effectively use the 50 kV winding of T 3 solely for active power transport without overloading, VSC-1shall be in reactive power control mode where the reference set point is zero.

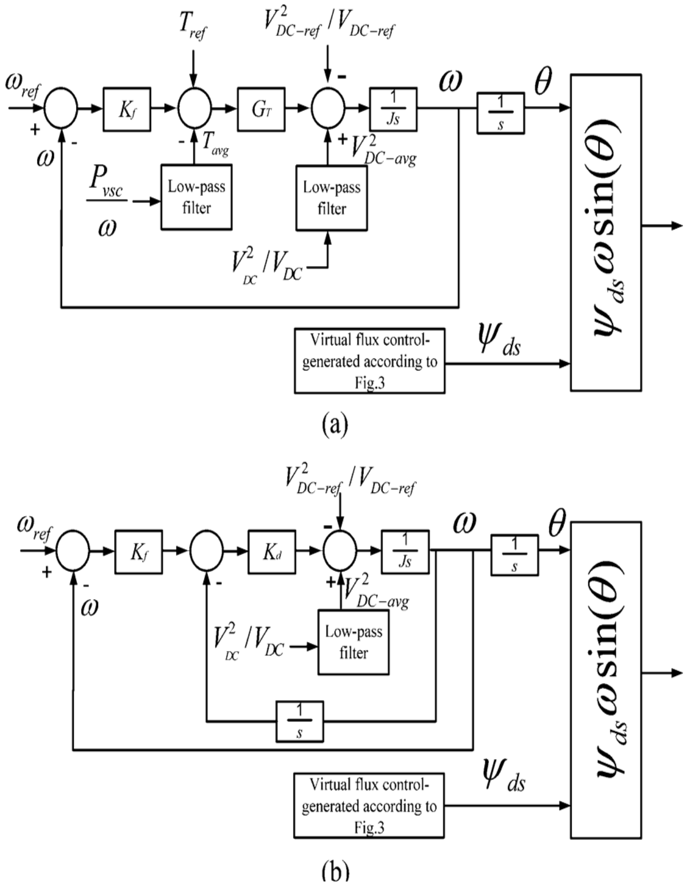


Fig. 3 Proposed control topologies for frequency and dc-link voltage regulation.(a) Virtual torque control. (b) Direct dc-link voltage control.

Moreover, in order to improve the voltage profile of Area 250 kVgrid, VSC-2 shall control the AC voltage at bus-2.The direct voltage and the active power control can be achieved by either of the two converters. Thus, we have two possible control strategies, VSC-1controls the reactive power and the active power VSC-2 controls the AC voltage and the direct voltage. VSC-1 controls the reactive power and the direct voltage VSC-2 controls the active power and the AC voltage. The choice between the two strategies depends mainly on two factors.

Area 2 consists of cables of longer length in its distribution and sub-transmission grid than Area 1. In addition, there are over headlines in Area 2 but not in Area 1. Thus the frequency of disturbances in Area2 is expected to be higher than in Area 1. Furthermore, disturbances in Area 2 cause larger voltage dipsatbus-2than disturbances in Area 1 cause at bus 8. As voltage dips hinder the performance of the VSC-HVDC controllers, the preferred strategy will be to have VSC-1controlthe direct voltage, which is Strategy-2. In this paper the control system is in Strategy-1under-normal condition but will switch to Strategy-2 in case of some disturbances.

The phase currents at both sides are affected after the step change is applied. The change in active power is reflected in the *d*-components of the AC currents and the direct current. Because of the decoupled control almost no effect is seen in the q-component VSC-1 current, i.e., reactive power control. The q-component of theVSC-2 current has changed to keep the AC- voltage at bus-2 at its set point. The response of the direct voltage only shows some minor transients at the beginning of the step change of the active power. The step change also results in minor transients in the voltages of bus-1and bus-2, the transient at bus-2 is large because of the slow AC-voltage controller compared to the active power controller.

III. PULSE WIDTH MODULATION

The pulse width modulation technique is used in proposed control system. Basically there are types of PWM techniques for Multilevel Inverters.

(a). Phase Shifted PWM:

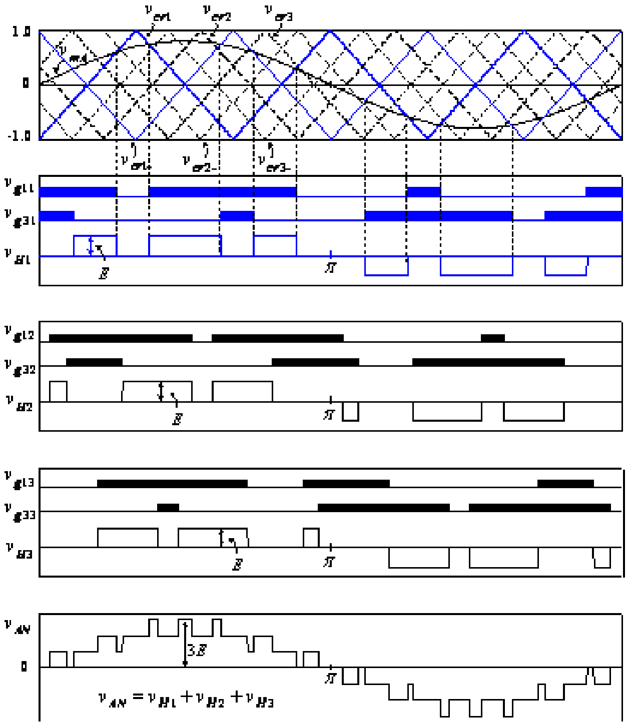
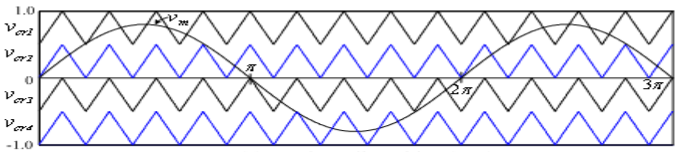


Fig. 4. Wave form of Phase Shifted PWM

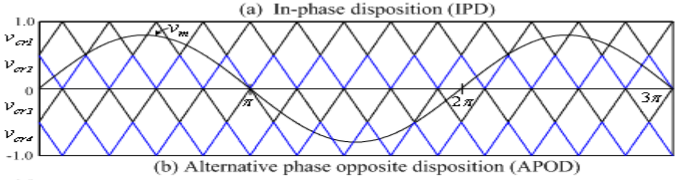
If the Number of voltages m=5, the number of carriers required are m_C-1=4 and the Phase shift=360^0/ m_C =90^0 The distortion factor and lower order harmonics are reduced significantly. The gating signals are generated by comparing a sinusoidal reference Signal with a triangular carrier wave of frequency Fc. The frequency of reference signal frequency determines the inverter output frequency and its peak amplitude controls the modulation Index M and RMS output voltage Vo. The number of pulses per half cycle depends on carrier Frequency.

(b). Level shifted PWM:

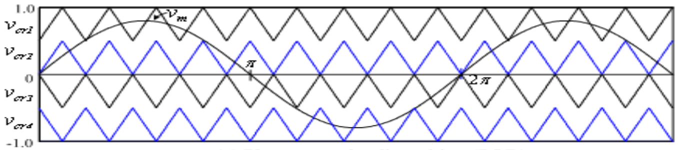
The merits and demerits of these two PWM techniques are compared under comparable circuit conditions on the basis of factors like (i) quality of output voltage (ii) obtainable magnitude of output voltage (iii) ease of control etc. The peak obtainable output voltage from the given input dc voltage is one important figure of merit for the inverter.



(a) In-phase disposition (IPD)



(b) Alternative phase opposite disposition (APOD)



(c) Phase opposite disposition (POD)

Fig. 5. Wave form of Level shifted PWM

IV. PROPOSED CONTROL SYSTEM

Nowadays, because of high penetration levels of renewable energy resources, the paradigms of micro grids (MGs) and distribution generation (DG) are gaining vital role in power and distribution systems. MGs are categorized as ac MGs, dc MGs, and hybrid ac–dc MGs. Since a considerable portion of renewable energy resources, such as wind turbines, photovoltaic (PV), fuel cells and energy storage systems, and many modern loads such as communication technology facilities, data centers, and motor drives is dc-type, dynamics and controls of rectifiers and dc MGs are gaining high interest. However, in dc grids, many generation units such as wind turbines must be interfaced to the utility grid via electronically interfaced (EI) rectifiers.

In addition, several modern ac loads are coupled to ac grids through back-to-back rectifier-inverter to provide variable frequency operation. Based on predictions given in, the resistive load share will be significantly reduced whereas the EI loads share will increase to 60% - 80% of the total load by 2015.

The conventional control topologies for three-phase converters are the voltage-oriented vector control and direct-power control. The dq components of the current vector are regulated by a controller generating appropriate values for the converter dq voltage components. A phase locked-loop (PLL) is required to transform current and voltage variables from the abc frame to the dq frame.

V. SIMULATION RESULTS

This section presents simulation results provides entire details of proposed control systems. Consider generating side conflicts and transmission side conflicts. Here two modes are selected rectification and inversion modes explanation by using MATLAB/SIMULINK results. The rectifier and the inverter are three-level VSC converters using close IGBT/Diodes.

(a). Rectifier side:

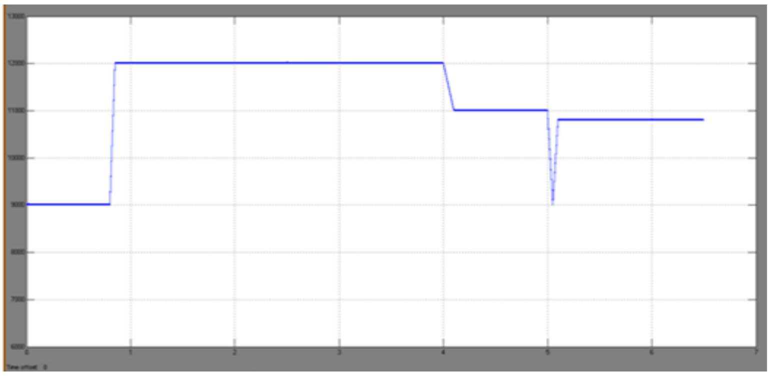


Fig. 6 Simulation results for rectifying mode Real power

In this simulation results explained, sudden changes power on load occur it can controlled within time The dc voltage encounters sag due to the load power change; however, the recovery time is less than 0.1 s, presenting a very fast response

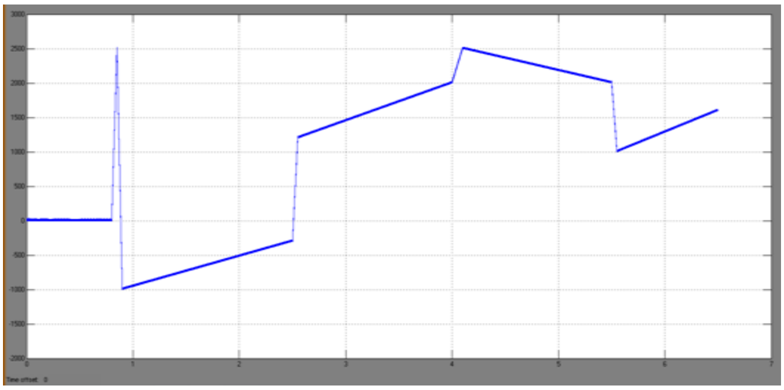


Fig. 7 Simulation results for rectifying mode Reactive power

The effect of reactive power set variation on the dc-link voltage is almost negligible which proves the decoupling between real and reactive power regulation

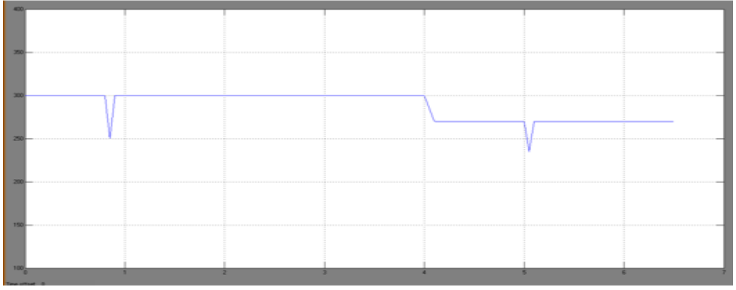


Fig. 8 Simulation results for rectifying mode DC voltage

In this case, the VSC provides the required reactive power to compensate for the voltage sag and it easily tracks the reference variation

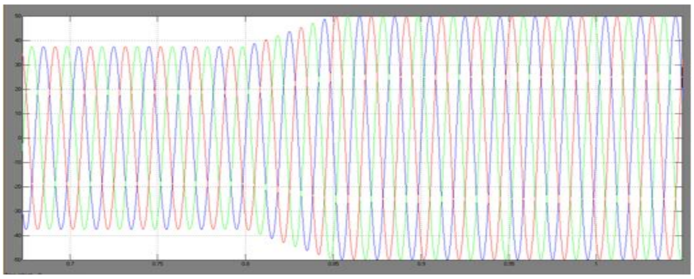


Fig.9. Current wave forms for the case of load power increment

In order to investigate the controller effect on the instantaneous current and voltage regulation in transient and steady state conditions, their waveforms for the case of load current increment from 30 A to 40 A.

(B). Inverter side:

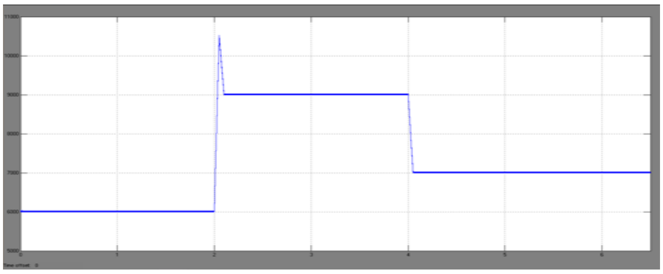


Fig.10 simulation results for inverting mode Real power

The time-domain responses are in agreement with the Eigen value analysis presented, which indicates the effectiveness of the designed controller.

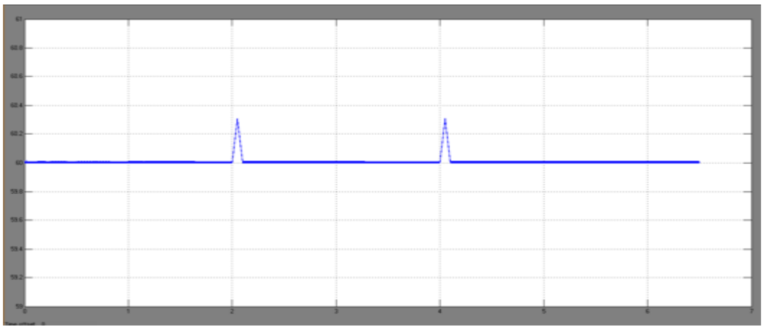


Fig. 11simulation results for inverting mode Frequency

The dc-link voltage reference is reduced to 250 V and the VSC tracks the reference value with highly damped transient response.

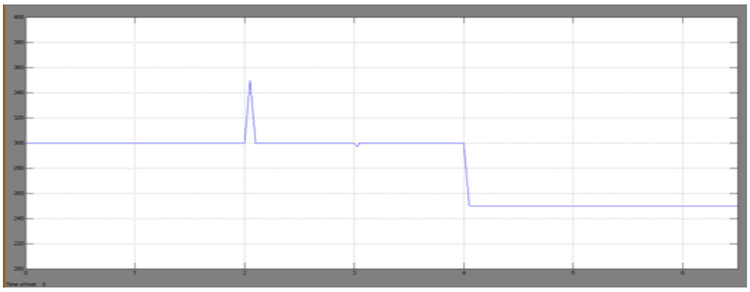


Fig.12. simulation results for inverting mode DC-link voltage

(C). Fault Ride through Capability:

The proposed controller emulates the characteristics of an SM with frequency and virtual flux regulation. The corresponding waveforms of the dc-link voltage, three-phase instantaneous currents, and output filter voltage are during the single phase fault, is reduced.

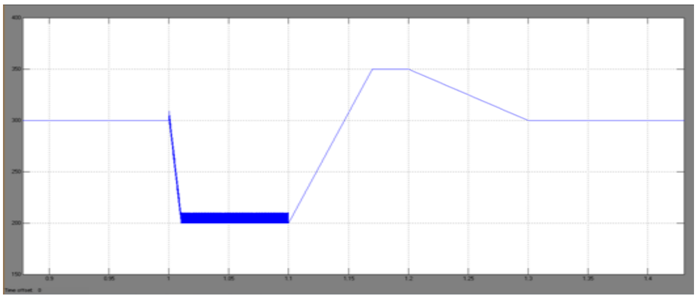


Fig. 13. Fault –ride-through capacity of the synchronous-VSC DC-link voltage

The amplitude of phase "b" current increases to 70 A during the fault whereas, in two other phases, the current amplitude is almost constant. As expected, the current waveforms are unbalanced and distorted.

(D). Vector Control:

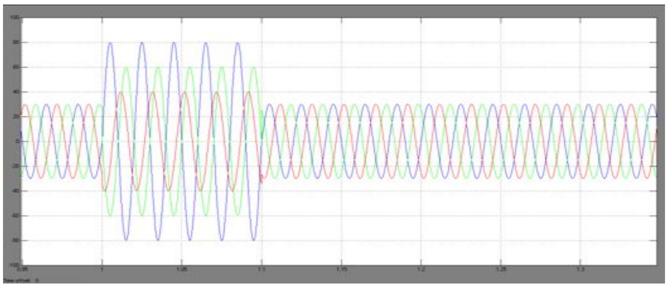


Fig.14. Fault –ride-through capacity of the synchronous-VSC Instantaneous currents.

This is due to the fact that the controller acts like a virtual SG and inherently produces some damping and synchronizing power which enable self-synchronization in various operating conditions.

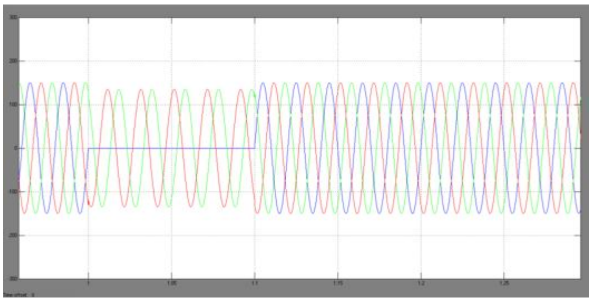


Fig.15. Fault –ride-through capacity of the synchronous-VSC Instantaneous output filter voltage

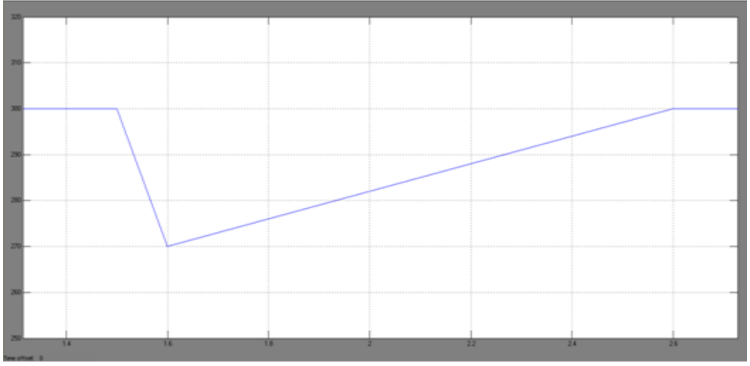


Fig. 16. response of the vector control for the case of the load power increment DC-link voltage.

The waveforms of and VSC's frequency for the case that the load current is increased from 30 to 40 A are presented as can be seen, the settling time for the synchronous-VSC is approximately 0.1 s whereas it increases to more than 1 s in the conventional vector control.

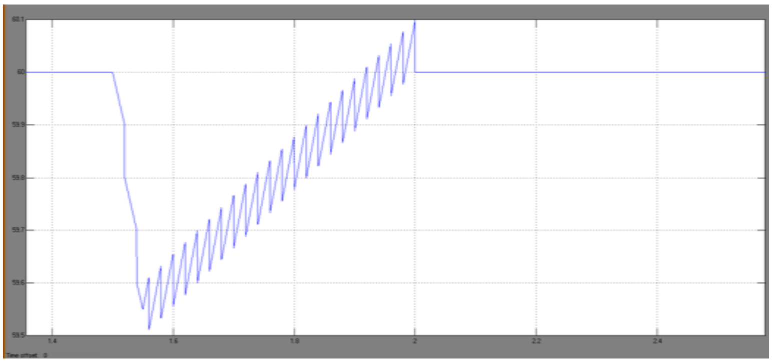


Fig. 17. system response of the vector control for the case of the load power increment VSC's frequency

(E). Virtual Torque Control Strategy

In the previous sections, the results for the direct dc-link voltage controller are presented. Here, the performance of the virtual torque controller The parameters of the frequency loop are as follows: (Kf=1000) Kt=30,Kti=2,J=10, based on the frequency error, the virtual torque reference is obtained and the virtual torque control loop adjusts the dc-link voltage in a way such that damping and synchronizing torques are generated within the controller during transients similar to SMs. The parameters of the simulated system and the virtual torque. This controller offers good real and reactive powers decoupling capability as, when the reactive power reference is altered at t=2.5 s, there is no observable change in the dc-link voltage.

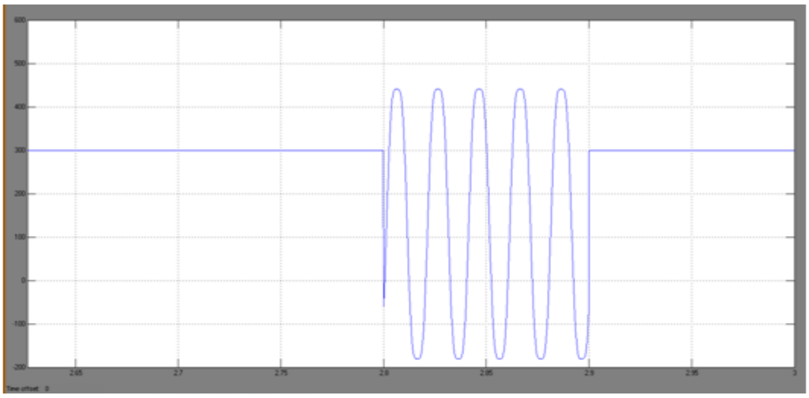


Fig. 18 System response during the fault using the vector control Dc-link voltage.

The system performance indexes in terms of speed of response and frequency regulation are similar to the direct dc-link voltage controller with more under and overshoot in the dc-link voltage response but less under and overshoot in the frequency.

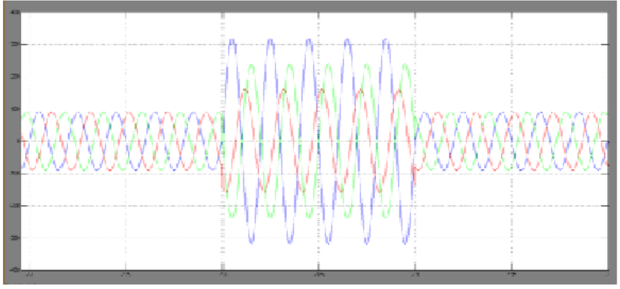


Fig. 19. System response during the fault using the vector control Instantaneous currents

The parameters of the simulated system and the virtual torque control loop parameters are the same as the previous case. Also, the same scenarios of section are applied to the system.

VI. CONCLUSION

A novel control topology for VSCs has been developed in the frequency-angle domain to regulate the dc-link voltage while providing 1) synchronizing and damping power components and 2) emulated inertia function to the VSC. These features are highly desirable in VSCs interfacing renewable energy resources, dc MGs and active converter-interfaced loads to weak ac systems. The proposed synchronous control topology offers the following advantages.

It is a new control topology implemented in the frequency angle domain, which simplifies converter integration and analysis in grids with conventional SGs.

The controller introduces some inertia and dynamics for frequency. In fact, the power grid views the dc-link capacitor as a virtual rotor with virtual inertia. The stored energy in the dc-link is employed to damp frequency oscillations during contingencies.

Since the controller presents damping and synchronizing power dynamics, similar to SMs, it can automatically synchronize itself with the grid and tracks its variations, thus there is no need for a

PLL after initial synchronization.

In the modeling and design process, the dc-link voltage dynamics are taken into account which provides a more general and accurate control framework. The controller offers fault-ride-through capability which enhancesthe overall system reliability.

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