Modeling and simulation of Dynamic Voltage Restorer with improved power quality features

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ABSTRACT

The series connected DVR will inject three-phase compensating voltages through the three-phase injection transformer or three single-phase injection transformers with the main supply. The filtered VSI output voltage is boosted to the desired level with the injection transformer. The transformer also isolates the DVR circuit from the distribution system. *The capacity of the voltage source inverter (VSI) and the values for the link filter connected between the injection transformer and the inverter play a crucial in the design of the DVR. In this research project, new Dynamic Voltage Restorer (DVR) topology has been proposed. The capacity of the voltage source inverter (VSI) and values of the link filter is small that will improve the compensation capabilities for voltage harmonic, swell and voltage sag mitigation under various fault conditions. The new RLC filter is able to eliminate the switching harmonics. The capacity of the dc supply voltage is reduced when the value of inductance is small. The new DVR topology has high efficiency and the ability to improve the quality of voltage. An outline architecture of the RLC filter parameters for the specific model has been presented. The new DVR with proposed* ***controlled Dynamic Voltage Restorer*** *topology is modeled and simulated using the MATLAB. The control scheme has good control dynamics with minimum transient current overshoot. The simulation results under transient performance are good.*

INTRODUCTION

Day to day there is an increase in the intensity of sensitive loads in power systems, so the power quality issues play a vital role in the present days. There are extreme power quality problems mentioned as voltage swell, voltage sag, harmonics, flicker etc. Voltage sag generally origin from the faults on load or supply side, maloperation, electrical motor startup, electrical heaters turning on, etc. So the DVR is mitigating the voltage sag through injecting the voltage. Power quality problems are affected due to the appearance of various non-linear loads such as diode bridge rectifiers, adjustable speed drives (ASD), switched mode power supplies (SMPS), laser printers etc.As stated on voltage sag is the reduction in RMS voltage from 0.1pu to 0.9pu for a short time period of 0.5 cycles to few cycles. Generally, faults occurred in distribution systems having a reduction from 40% to 50% of the rated voltage until less than 2secs. Due to the above mentioned power quality problems on sensitive loads, minimization their effects are necessary. Furthermore, new power electronic devices are introduced and named as custom power devices. These devices are distribution static compensator (D-STATCOM), unified power quality conditioner (UPQC), dynamic voltage restorer (DVR). DVR is the perfect solution for restoring the load voltage at output terminals. When, the quality of source voltage is disturbed. DVR compensate the voltage sag with an appropriate injection of voltage in series with grid voltage, in order to maintain the rated load voltage with balance mode condition. Generally, DVR consists of inverter, injection transformer and energy storage device. The design of new inverter topology is to inject the voltage with proper control of the magnitude and phase angle, to maintain the constant load voltage and avoid disturbances at load voltage. The basic system model of DVR

DVR is a power electronic switching device which is connected in series to the load voltage bus to inject a dynamically controlled voltage. This voltage can eliminate effects of fault of voltage bus on a sensitive load. DVR is equipment used to recover a voltage or improve the voltage quality on the load side and its position is mounted in series between the source and the load. DVRs are coupled in series with distribution systems to protect sensitive equipment against the occurrence of voltage drop. The basic function of the DVR is to detect the occurrence of voltage drops that occur on the power system channel, and then inject the voltage to compensate for the voltage drop that occurs. Therefore the DVR is placed close to the sensitive load that is protected. The DVR works depending on the type of interference or an event occurring in the system, generating the injected voltage obtained from the DC energy storage unit and then converted to AC voltage by the voltage source inverter (VSI. To set the controller on the DVR is used dq0 transformation or Park transformation. The dq0 method will provide information on the depth of the voltage drop and the phase shift with the starting point and end point of the voltage drop.

Literature survey

Johan H. R. Enslin and Peter J. M. Heskes,[1]

"Harmonic interaction between a large number of distributed power inverters and the distribution network,"

In this paper discussed the harmonic interaction between a large number of distributed power inverters and the distribution network. This paper is to analyze the observed phenomena of harmonic interference of large populations of these inverters and to compare the network interaction of different inverter topologies and control options.

UffeBorup, FredeBlaabjerg and Prasad N. Enjeti ,[2]

"Sharing of nonlinear load in parallel-connected three-phase converters,"

Presented about the sharing of linear and nonlinear loads in three-phase power converters connected in parallel, without communication between the converters. The paper focuses on solving the problem that arises when two converters with harmonic compensation are connected in parallel.

POWER QUALITY AND ITS PROBLEMS

Electric systems and grids are complex dynamic systems. These systems suffer usually from unexpected or sudden changes of the currents and voltages. These changes are due mainly to the different types of linear and non-linear loads to which they are connected. In addition, to different types of accidents which can intervener into the grid. With the increasing use of power semiconductors in the most of industrial and domestic procedures, the electric grids are polluted with different harmonic currents and voltages. These harmonics affect the normal function of the most of the grid connected devices; in addition to considerable economic losses. Many classic and modern solutions have been proposed in the literary for the harmonic problems. In this chapter, the harmonic problem as one of the most common power quality problems will be presented. The different modern and traditional solutions will then be discussed.

Definition of Power Quality

Power quality is a term that means different things to different people. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "The concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment." As appropriate as this description might seem, the limitation of power quality to "sensitive electronic equipment" might be subject to disagreement. Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

PROPOSED DVR CONFIGURATION

Series active power filter compensates current harmonics by injecting equal-but-opposite harmonic compensating currents into the grid. In this case the series active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non-linear load and the active power filter as an ideal resistor. The current compensation characteristics of the series active power filter is shown in Fig

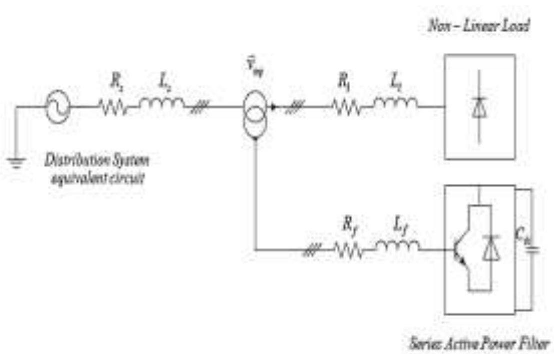

Fig. 1 Compensation Characteristic of DVR

Control Methods of VSI

The aim of the control of the VSC is to force the output currents of the inverter to follow their predefined reference currents. The main principle is based on the comparison between the actual current of the filter with the reference currents generated by the different extraction methods. In the next section, we are going to discuss some different methods in VSC control.

The current control strategy plays an important role in fast response current controlled inverters such as the active power filters. The hysteresis current control method is the most commonly proposed control method in time domain. This method provides instantaneous current corrective response, good accuracy and unconditioned stability to the system. Besides that, this technique is said to be the most suitable solution for current controlled inverters.

Hysteresis current control is a method of controlling a voltage source inverter so that an output current is generated which follows a reference current waveform.

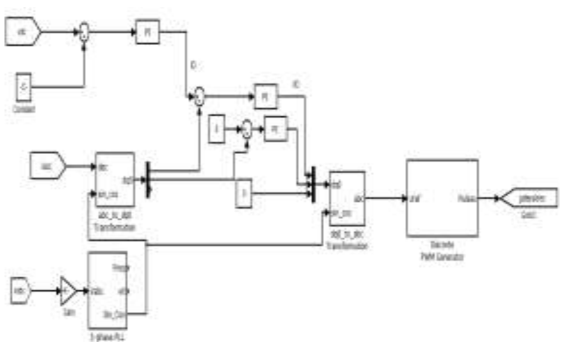

Fig. 2 Proposed controller.

RENEWABLE ENERGY SOURCES

The most common definition is that renewable energy is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed. Renewable energy is a subset of sustainable energy.

India has done a significant progress in the power generation in the country. The installed generation capacity was 2300 megawatt (MW) at the time of Independence i.e. about 60 year's back. Which includes the generation through various sectors like Hydro, Thermal and Nuclear. The power generation in the country is planned through funds provided by the Central Sector, State Sector and Private Sector. The power shortages noticed is of the order of 22%. In the opinion of the experts such short fall can be reduced through proper management and thus almost 20% energy can be saved. It has been noticed that one watt saved at the point of consumption is more than 2.5 watts generated. In terms of Investment it costs around Rs.20 million to generate one MW of new generation plant, but if the same Rs.20 million is spent on conservation of energy methods, it can provide up to 3 MW of avoidable generation capacity.

PROPOSED DVR SIMULATION RESULT

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration.

BLOCK DIAGRAM

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs. Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time.

MODEL EXECUTION PHASE

In the simulation model execution phase, Simulink successively computes the states and outputs of the system at intervals from the simulation start time to the finish time, using information provided by the model. The successive time points at which the states and outputs are computed are called time steps. The length of time between steps is called the step size. The step size depends on the type of solver used to compute the system's continuous states, the system's fundamental sample time, and whether the system's continuous states have discontinuities (Zero Crossing Detection). At the start of the simulation, the model specifies the initial states and outputs of the system to be simulated. At each step, Simulink computes new values for the system's inputs, states, and outputs and updates the model to reflect the computed values. At the end of the simulation, the model reflects the final values of the system's inputs, states, and outputs. At each time step:

Simulink Updates the outputs of the models' blocks in sorted order. Simulink computes a block's outputs by invoking the block's output function. Simulink passes the current time and the block's inputs and states to the output function as it may require these arguments to compute the block's output. Simulink updates the output of a discrete block only if the current step is an integral multiple of the block's sample time.

Updates the states of the model's blocks in sorted order. Simulink computes a block's discrete states by invoking its discrete state update function. Simulink computes a block's continuous states by numerically integrating the time derivatives of the continuous states. It computes the time derivatives of the states by invoking the block's continuous derivatives function.

Optionally checks for discontinuities in the continuous states of blocks. Simulink uses a technique called zero crossing detection to detect discontinuities in continuous states.

SIMULATION CIRCUIT WITHOUT NOVEL DVR

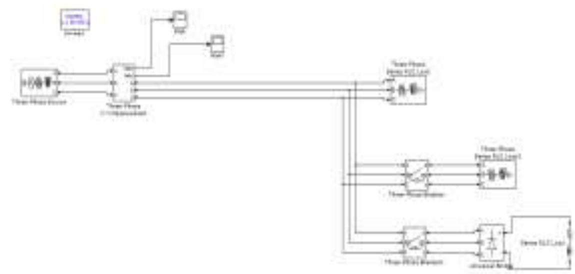

Fig 3 :Circuit without DVR

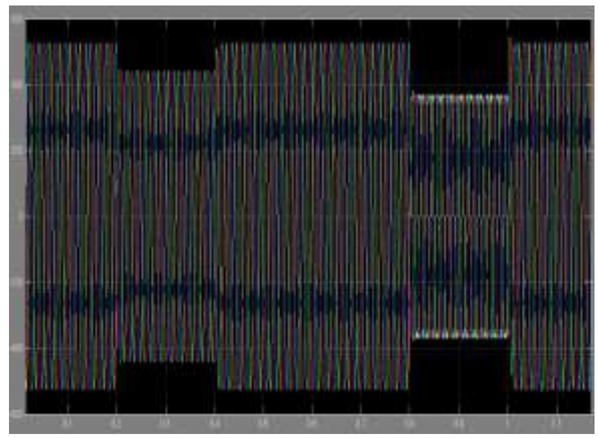

Fig 4 :Voltage profile without DVR

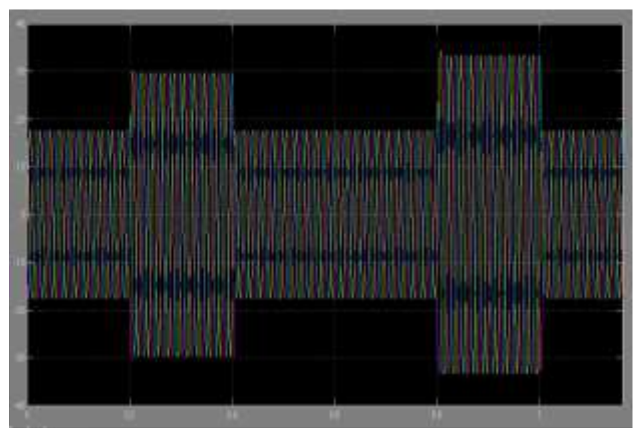

Fig 5 :Current profile without DVR

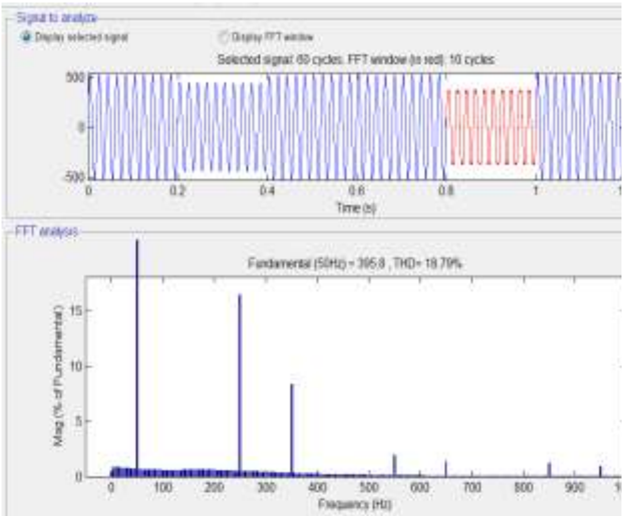

Fig 6 :Total harmonic distortion

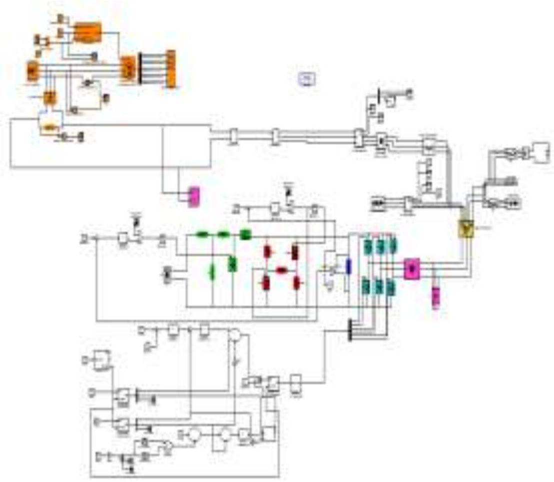

Fig 7 :Total circuit configuration with existing controller

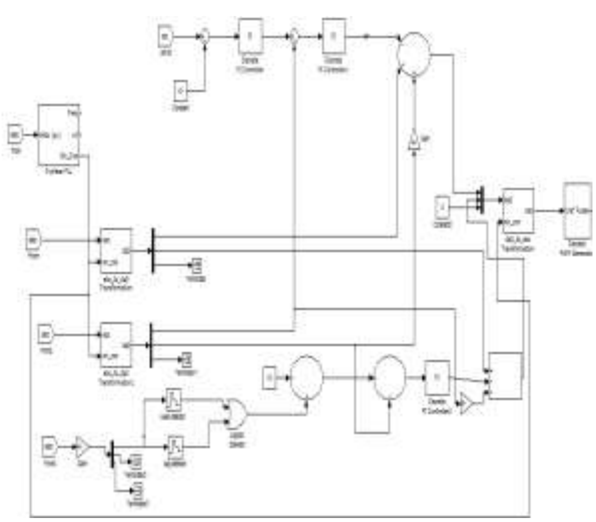

Fig 8 :Simulink diagram for existing controller

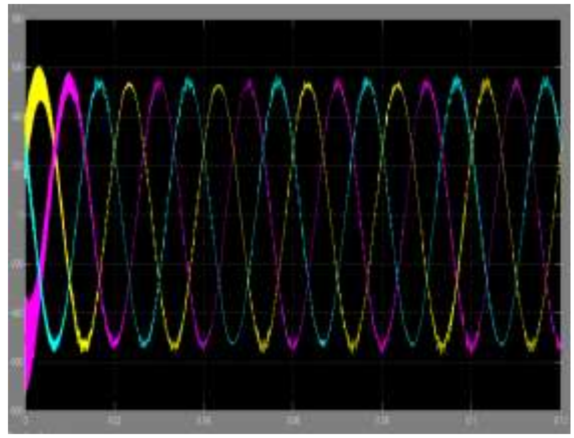

Fig 9 :Voltage profile with existing controller

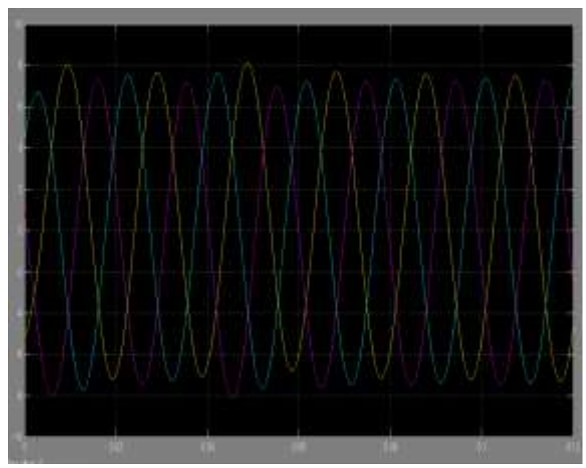

Fig 10 :Current profile with existing controller

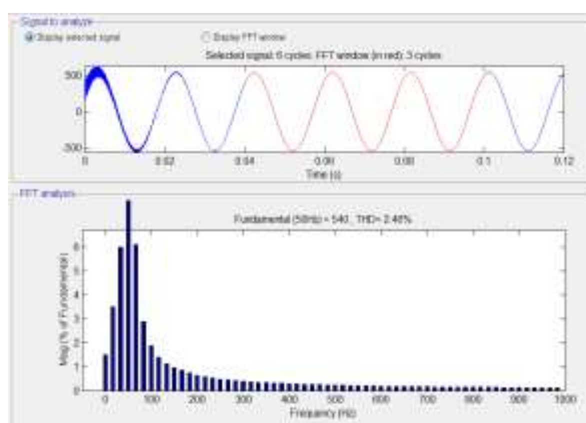

Fig 11 :Total harmonic distortion existing controller

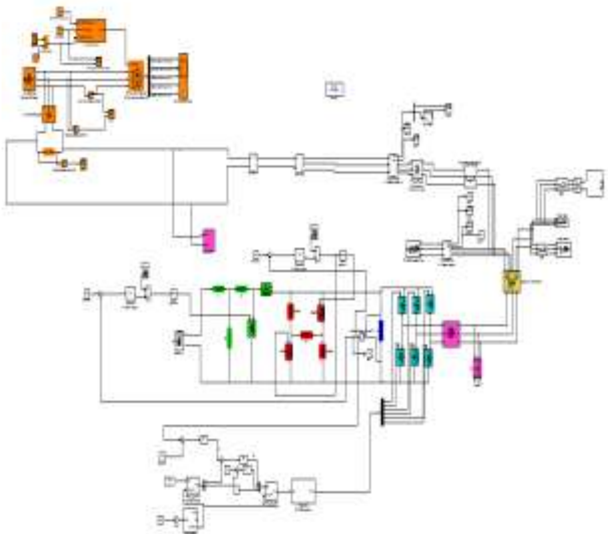

Fig 12 :Total circuit with proposed controller

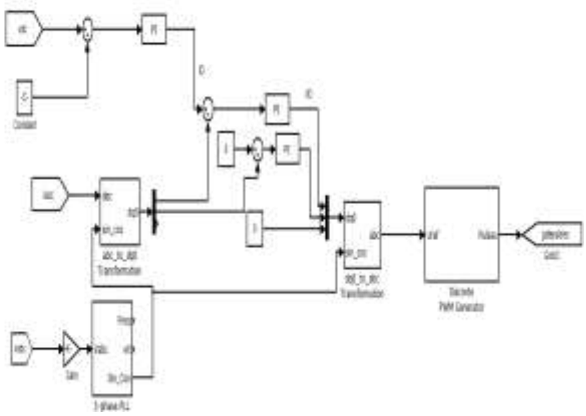

Fig 13 :Simulink diagram for proposed controller

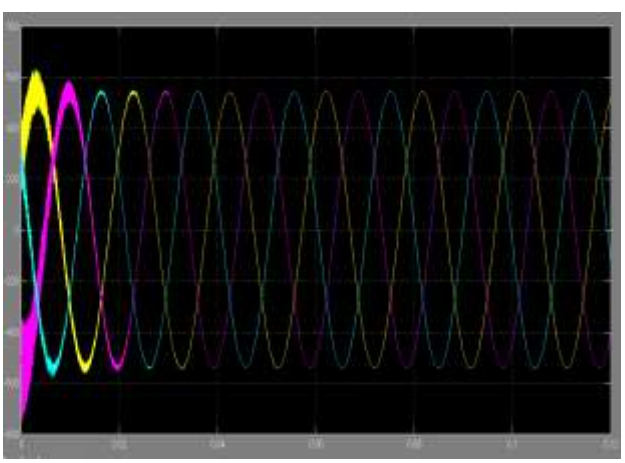

Fig 14 :Voltage profile with proposed controller

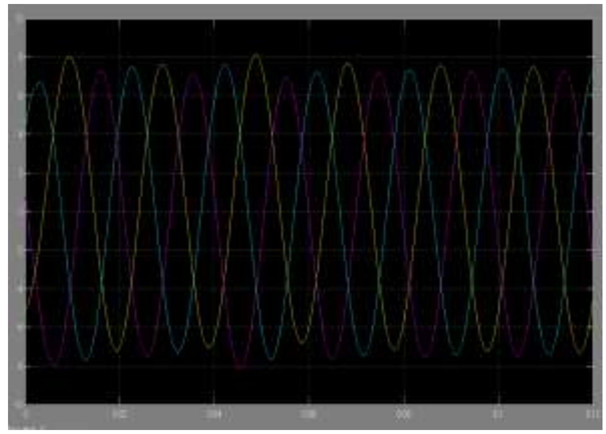

Fig 15 :Current profile with proposed controller

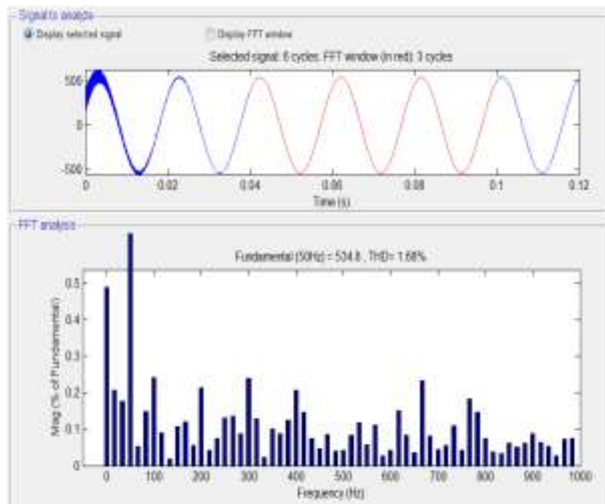

Fig 16 : Total harmonic distortion proposed controller

CONCLUSION

The simulation results show that the proposed DVR is capable of repairing power quality interference. The DVR control block will detect the disturbance of voltage that occurs and the DVR functions as a compensator. phase injection transformer or three single-phase injection transformers with the main supply. The filtered VSI output voltage is boosted to the desired level with the injection transformer. The transformer also isolates the DVR circuit from the distribution system. The capacity of the voltage source inverter (VSI) and the values for the link filter connected between the injection transformer and the inverter play a crucial in the design of the DVR. In this research project, new Dynamic Voltage Restorer (DVR) topology has been proposed. The capacity of the voltage source inverter (VSI) and values of the link filter is small that will improve the compensation capabilities for voltage harmonic, swell and voltage sag mitigation under various fault conditions. The new RLC filter is able to eliminate the switching harmonics. The capacity of the dc supply voltage is reduced when the value of inductance is small. The new DVR topology has high efficiency and the ability to improve the quality of voltage. An outline architecture of the RLC filter parameters for the specific model has been presented. The new DVR with proposed controlled Dynamic Voltage Restorer topology is modeled and simulated using the MATLAB. The control scheme has good control dynamics with minimum transient current overshoot. The simulation results under transient performance are good.

REFERENCES

[1] C. Tu, Q. Guo, F. Jiang, H. Wang, and Z. Shuai, "A comprehensive study to mitigate voltage sags and phase jumps using a dynamic voltage restorer," IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 2, pp. 1490–1502, 2020.

[2] A. P. Torres, P. Roncero-Sanchez, and V. F. Batlle, "A two degrees of freedom resonant control scheme for voltage-sag compensation in dynamic voltage restorers," IEEE Transactions on Power Electronics, vol. 33, no. 6, pp. 4852–4867, 2017.

[3] S. Priyavarthini, A. C. Kathiresan, C. Nagamani, and S. I. Ganesan, "Pvfeddvr for simultaneous real power injection and sag/swell mitigation in a wind farm," IET Power Electronics, vol. 11, no. 14, pp. 2385–2395, 2018.

[4] Y. Zhang and C. Qu, "Direct power control of a pulse width modulation rectifier using space vector modulation under unbalanced grid voltages," IEEE Transactions on Power Electronics, vol. 30, no. 10, pp. 5892–5901, 2014.

[5] C. Meyer, R. W. De Doncker, Y. W. Li, and F. Blaabjerg, "Optimized control strategy for a medium-voltage dvr¡ a theoretical investigations and experimental results," IEEE Transactions on Power Electronics, vol. 23, no. 6, pp. 2746–2754, 2008.

[6] F. Jiang, C. Tu, Q. Guo, Z. Shuai, X. He, and J. He, "Dual-functional dynamic voltage restorer to limit fault current," IEEE Transactions on Industrial Electronics, vol. 66, no. 7, pp. 5300–5309, 2019.

[7] A. dos Santos, T. Rosa, and M. T. C. de Barros, "Stochastic characterization of voltage sag occurrence based on field data," IEEE Transactions on Power Delivery, vol. 34, no. 2, pp. 496–504, 2018.

[8] J. L. Sosa, M. Castilla, J. Miret, J. Matas, and Y. Al-Turki, "Control strategy to maximize the power capability of pv three-phase inverters during voltage sags," IEEE Transactions on Power Electronics, vol. 31, no. 4, pp. 3314–3323, 2015.

[9] S. Choi, J. Li, and D. M. Vilathgamuwa, "A generalized voltage compensation strategy for mitigating the impacts of voltage sags/swells," IEEE Transactions on Power Delivery, vol. 20, no. 3, pp. 2289–2297, 2005.

[10] M. Castilla, J. Miret, A. Camacho, J. Matas, and L. G. de Vicuna, "Voltage support control strategies for static synchronous compensators under unbalanced voltage sags," IEEE Transactions on Industrial Electronics, vol. 61, no. 2, pp. 808–820, 2013.

[11] J. Wang, Y. Xing, H. Wu, and T. Yang, "A novel dual-dc-port dynamic voltage restorer with reduced-rating integrated dc¨cdc converter for wide-range voltage sag compensation," IEEE Transactions on Power Electronics, vol. 34, no. 8, pp. 7437–7449, 2019.

[12] A. Parre ˜ nno Torres, P. Roncero-S˜ nanchez, J. V˜nazquez, F. J. L ˜ nopezAlcolea, nd E. J. Molina-Mart˜ ninez, "A discrete-time control method for fast transient voltage-sag compensation in dvr," IEEE Access, vol. 7, pp. 170 564–170 577, 2019.

[13] V. Valouch, M. Bejvl, P. ˇ Simek, and J. ˇ Skraml˜ ik, "Power control of grid-connected converters under unbalanced voltage conditions," IEEE Transactions on Industrial Electronics, vol. 62, no. 7, pp. 4241–4248, 2014.

[14] M. Pradhan and M. K. Mishra, "Dual p- q theory based energyoptimized dynamic voltage restorer for power quality improvement in a distribution system," IEEE Transactions on Industrial Electronics, vol. 66, no. 4, pp. 2946–2955, 2019.

[15] T. A. Naidu, S. R. Arya, and R. Maurya, "Multiobjective dynamic voltage restorer with modified epll control and optimized pi-controller gains," IEEE Transactions on Power Electronics, vol. 34, no. 3, pp. 2181–2192, 2018.