

Compensation of Voltage Single-Phase SAG and SWELL Using Dynamic Voltage Restorer and Difference Per-Unit Value Method

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ABSTRACT

Recently, the demand for high power quality by customers has increased significantly. Common power equipment to protect sensitive loads against voltage disturbances in distribution networks, which are known by D-FACTS devices include: D-STATCOM, DVR and UPQC. Consequences resulting from industrial processes can be classified into two categories that are nonlinear and unbalanced loads and high vulnerability to transient faults (such as voltagesag) in distribution systems. DVR is a equipment which was connected in series and adjusting the loading voltage by feeding the voltage in system. The first installation was in 1996. Usually DVR installed between sensitive loads feeder and source in distribution system. The main duty, fast support load voltage (by fast detection algorithm) during disturbance to avoid any disconnection. In this paper approaches to compensate for voltagesag and swell as a common disturbance in voltage transmission and distribution networks is presented. A dynamic voltage restorer based on the average detection method for single-phase is discussed, in the other hand this paper describes the effect to using DVR in order to restoring the voltage sag and swell by difference per-unit value method (average detection) in distribution system. The result of single-phase voltagesag and swell simulation has been presented by SIMULINK/MATLAB.

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1. INTRODUCTION

Any variation in voltage, current and frequency quantities, which causes damages or inaccurate performance of using equipments, is recognized as disturbance power quality. One of the phenomenon of power quality voltage flash is, the decrease of voltage magnitude with short period (0.5 cycle to one minute), the reason is the short circuit in network or installation of high capacity motors (Generator) which many problems for electricity manufacturer. The main reason of attention to power quality is economical subjects. Various actions can be used by manufacturer, customers and equipments produce to decrease the quantity and severity voltage sags and reducing the sensitivity of equipments during voltage sags, the preventing in lowest level near to load is the cheapest way for restoring. One of the solution to improvement the power quality is using of FACTS-Devices in distribution system. Dynamic voltage restorer (DVR) is one of the device which is connect series to network and near to customer by feeding three-phase AC controlled voltage, restore voltage sag immediately [1]. In this paper, approaches for compensating the voltage sag and swell as a common disturbance in voltage

distribution networks is presented. After introduction in second section, the restoring methods for voltage sag which are using in distribution system has been pointed. In the third section, to introduce the modeling one of the newest and most efficient way in series compensated distribution network called dynamic voltage compensator (DVR) has been discussed. The fourth part of this paper, simulations are presented. Finally, conclusion and summarized of all the subjects in this paper is given in Section 5.

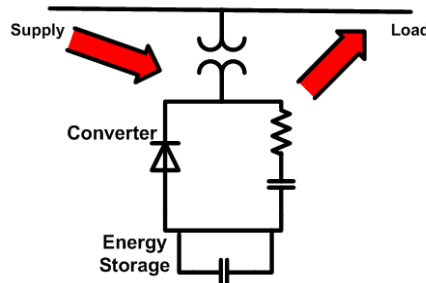


Figure 1. General plan of the DVR [2]

2. METHOD OF RESTORING FOR VOLTAGE SAG

In this part the methods and related defects has been presented.

2.1. Tap Changing Transformers

Electronic tap changing is achieved via the use of back to back thyristors (SCR) with a tap changing transformer. Has a reasonable response time (1 cycle) and is popular for medium power applications (>3kVA). However, high control resolution requires large number of SCRs. the control for fast response becomes fairly complex. Another drawback of this scheme is its susceptibility to high transient current with motor loads upon tap changing and its poor transient voltage rejection [2].

2.2. Saturable Reactor Regulators

This plan is simple and output voltage can be controlled by changing the impedance of saturable reactor. one of the problems is slow response (10 cycle) and high out impedance which makes disturbance in non-linear sensitive loads in coefficient load power factor [2].

2.3. Phase controller regulators

This technique uses phase controlled thyristors with LC filter to control output voltage. It has a slow response, high distortion especially with non-linear loads, over sized filters, very poor input line harmonics and will not handle surge currents such as motor starting [2].

2.4. Electronic voltage regulators

They are a new class of automatic voltage regulators based on high frequency switching inverter technology. It can provide fast response (1-2 ms), sinusoidal voltages, and compact design [2].

2.5. Static voltage regulators (SVR)

This device, through the use of static tap changers, simply regulates the voltage to equipment operational levels. The SVR is able to correct voltage sag conditions (a 55% of the normal voltage maximum depth) in a quarter of a cycle (4 ms), to allow even the most sensitive manufacturing equipment to ride through voltage sag conditions caused by faults in the utility distribution or transmission systems [2].

2.6. Ferroresonant Transformers (CVT)

Ferroresonant transformers, also called constant-voltage transformers (CVT), can handle most voltage sag conditions (always beneath 20 kVA). The ferroresonant regulator has a response time of about 25 ms or 1.5 cycles. More important are its high output impedance (again up to 30% of load impedance), sensitivity to both leading and lagging load power factors, and low efficiency at partial loads. In summary, the ferroresonant regulator is useful in small systems that do not contain large motors [2].

2.7. Dynamic Voltage Restorer (DVR)

This method immediately restorer and clear the voltage sag. Quick response (< 1 ms), low waste conductivity switching is the main specifications [2].

3. DVR INTRODUCING

Dynamic Voltage Restorer is a series connected device that injects voltage into the system in order to regulate the load side voltage. The DVR was first installed in 1996. It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load-side voltage in the event of a disturbance in order to avoid any power disruption to that load there are various circuit topologies and control schemes that can be used to implement a DVR. In addition to its main task which is voltage sags and swells compensation, DVR can also added other features such as: voltage harmonics compensation, voltage transients, reduction and fault current limitations. The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system as shown in Figure 2[3],[4],[5].

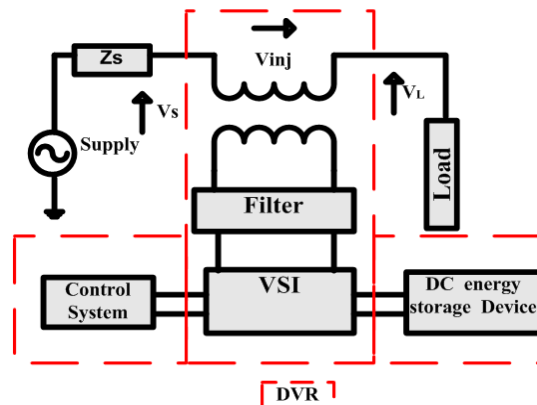


Figure 2. Structure of DVR[3]

1. **Voltage Injection Transformer:** The basic function of this transformer is to connect the DVR to the distribution network via the HV-windings and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage. The design of this transformer is very crucial because, it faces saturation, overheating, cost and performance. The injected voltage may consist of fundamental, desired harmonics, Switching harmonics and dc voltage components. If the transformer is not designed properly, the injected voltage May saturate the transformer and result in improper operation of the DVR [3],[6].
2. **Output Filter:** The main task of the output filter is to keep the harmonic voltage content generated by the voltage source inverter to the permissible level. It has a small rating approximately 2% of the load VA[3],[6].
3. **Voltage Source Inverter:** A VSI is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, Magnitude, and phase angle. In the DVR application, the VSI is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing [3],[6].
4. **DC Energy Storage Device:** The DC energy storage device provides the real power requirement of the DVR during compensation. Various storage technologies have been proposed including flywheel Energy storage, super-conducting magnetic energy storage (SMES) and Super capacitors these have the advantage of fast response. An alternative is the use of lead-acid battery Batteries were until now considered of limited suitability for DVR applications since it takes considerable time to remove energy from them. Finally, conventional capacitors also can be used [3],[6].
5. **Control system:** The aim of the control system is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances [6].

4. CASE STUDY AND SIMULATION RESULT

In Figure 3, the model of circuit for single-phase voltage detection and compensation sag is depicted. As can be seen for compensation single-phase disturbance, three single-phase inverter bridges are used. Also three single-phase Breaker for connection inverter output to transformer has been used since the time of the single-phase voltage sag should be closed single-phase Breaker faulty, and two healthy phases breakers remain open. Also for detecting the disturbance occurrence time, conversion dq unused, this converts when, the voltage and current disturbance that are balanced causes simplifies the control system and reduce

the detection time, because at balance disturbance, the output of this converts is DC, but in the single-phase disturbance, conversion of dq does not show variation of values moment DC, so the output of this convert has a ripple component 100Hz which has twice the frequency of the voltage source. Thus to achieve the DC values, needed low-pass filter or filter slot 100Hz. But these filters causing delays in voltage detection and eventually time detection will increase. Thus indetection of unbalanced disturbance, other detection methods such as average, RMS or peak is used [7].

In the circuit of Figure 3, difference per-unit values method have been used. Block inverter system is shown in Figure 4. In this circuit, a single-phase fault in Bus1 occur in 0.15 second which causes %75 voltage sag during 0.2 second and restores in 0.35 second by safely devices. The total time of simulation is 0.5 second.

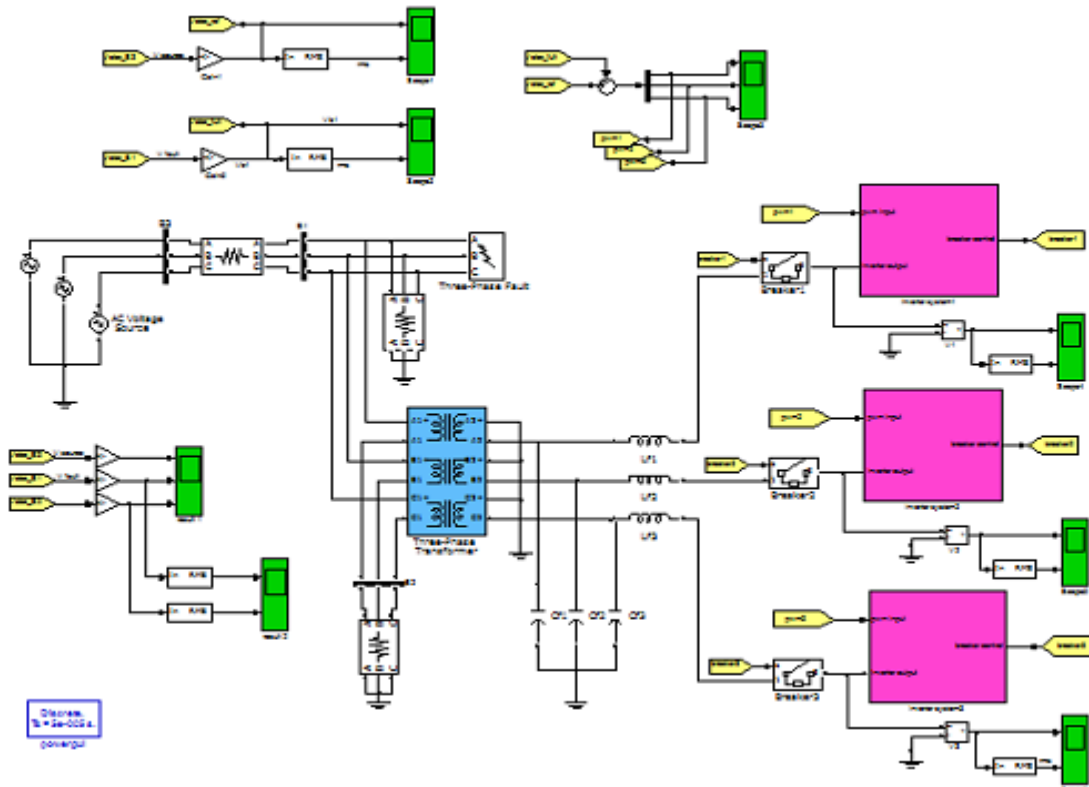


Figure 3. Modeling circuit for Detecting and compensating voltage single-phase sag and swell in MATLAB / SIMULINK

4.1. PARAMETERS AND ELEMENT OF CIRCUIT

In table 1 parameters and constant factors in simulated circuit is mentioned.

Table 1. Circuit parameters

Parameter	Value
Main Supply Voltage per phase	200 V
Supply Voltage DC	V160
Line Frequency	50 HZ
Series transformer turns ratio	1:1
Line Impedance	$L_s=0/5$ mH $R_s=0/1$ Ω
Load Impedance	40 Ω
Asaw-tooth carrier wave frequency	HZ1800
K	1
Filter Inductance	4mH
Filter capacitance	10 μ F

4.2. CIRCUIT FUNCTION AND SIMULATION RESULTS

In this circuit, three-phase voltages at bus B3 as reference voltages to be monitored are shown in Figure 5. Three-phase voltages bus B1 are also recorded as a voltage fault (Figure 6), in this figure clearly be seen that a phase voltage has dropped sharply. Voltage swell can be seen in Figure 7. Then difference between two voltage as the voltage-controlled PWM is given to the block inverter system that seen in Figure 8, this difference is zero for the two healthy phases.

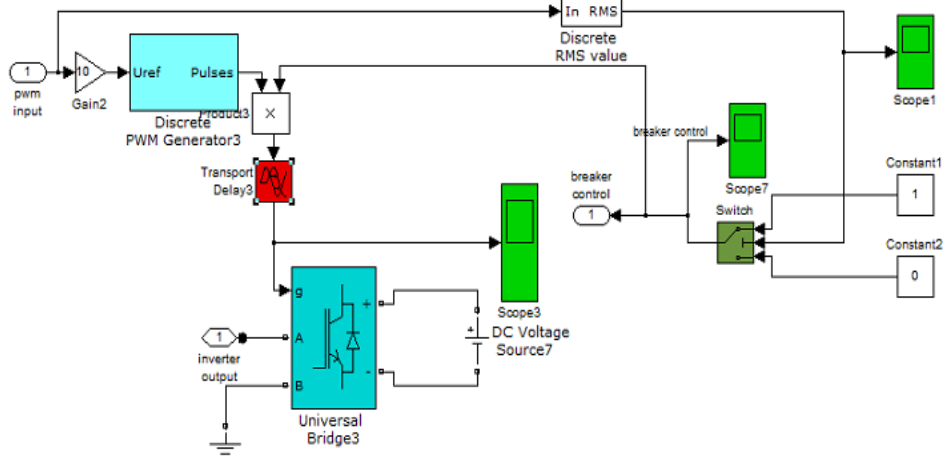


Figure 4. The Inverter System block diagram in MATLAB / SIMULINK

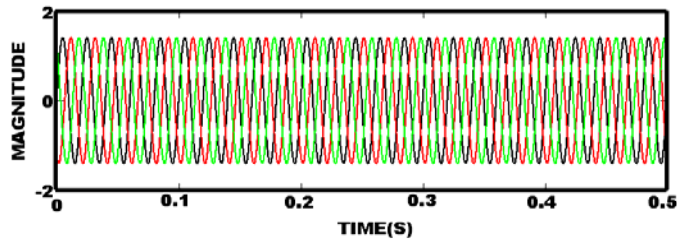


Figure 5. B3 bus voltage as reference voltage

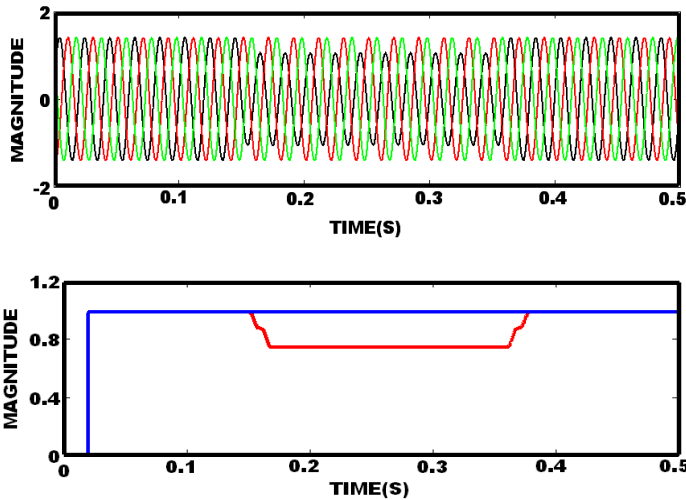


Figure 6. B1 bus voltage under a single-phase voltage sag (75%) in the form a) b) an effective amount of voltage

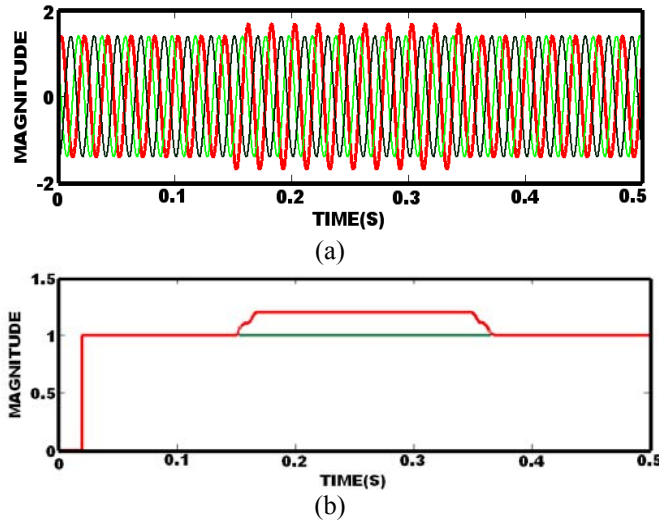


Figure 7. B1 bus voltage under a single-phase voltage swell; a) in the form a b) an effective amount of voltage

As was observed in Figure 3, in inverter system block, the input convert to the rms and then applied to the switch and produce a (0-1) zero signal, Multiplied by the output of the PWM block and injected into single-phase inverter full-bridge gate. Figure 9, show that the effective voltage switch input and output signal for the depressed phase. The requirement to switch output1, input is equal or higher than 0.1 switches has out put to prevent detection of lower 10% voltage sag. This can be seen in Figure 9(b) a delay. Breaker result is the same condition. When PWM1 effective voltage is more than 0.1, connected Breaker command is given, Effective voltage switch input and output signals for healthy phases are zero. Figure 10 show that injection pulses to the inverter gate for faulty phase. At Healthy phases, because PWM input and output switch is zero, input of the inverter gate will be zero, Therefore inverter output is also zero.

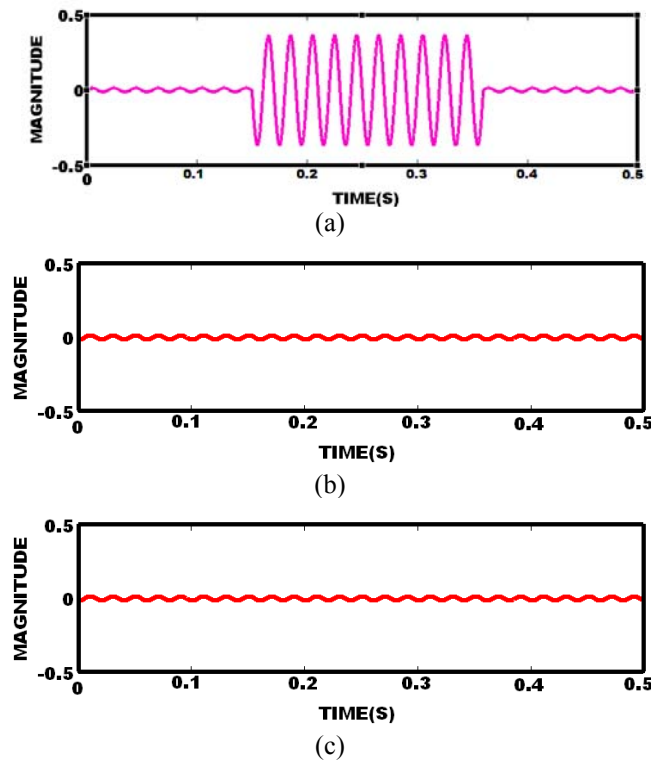


Figure 8. Difference reference voltage and the fault voltage as a voltage controlled pwm a) pwm1 b) pwm2 c) pwm3.

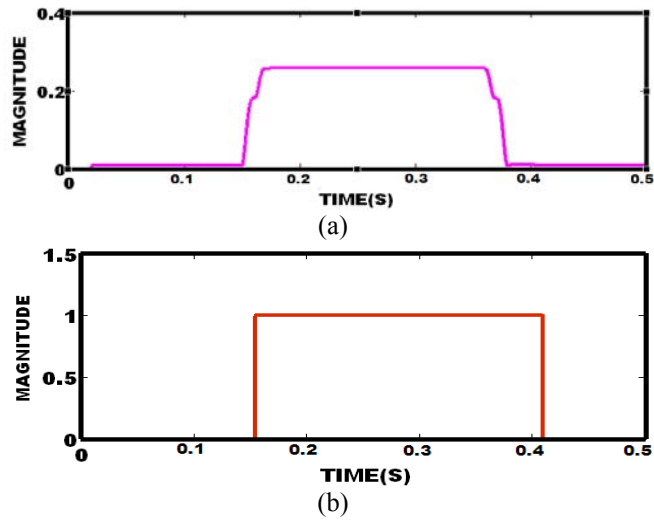


Figure 9. a) an effective amount of the block input inverter system 1 b) control signal Breaker in depressed phase

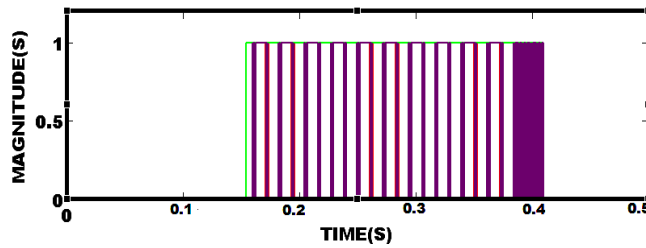


Figure 10. Injection pulses to the inverter gate in a depressed phase

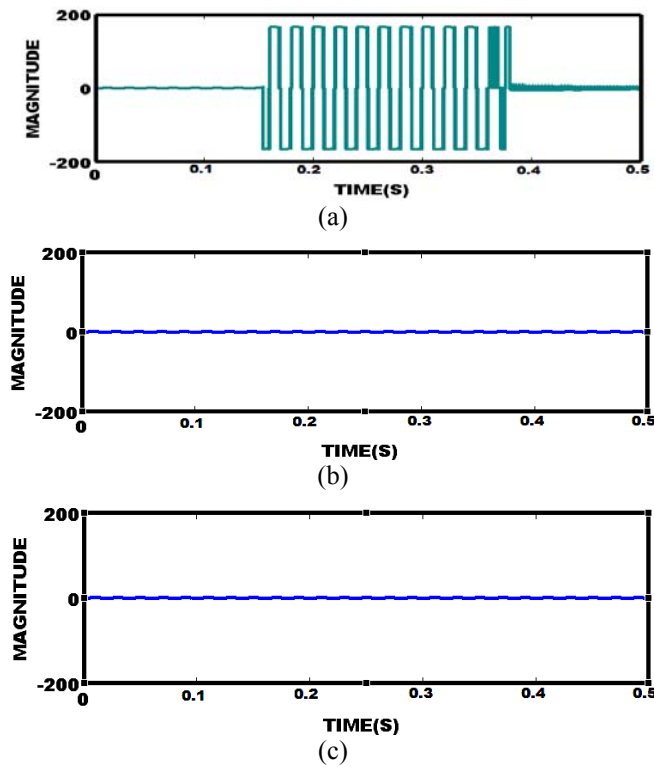


Figure 11. Single-phase inverter output at compensating circuit in a single-phase) Vinv1 b) Vinv2 c) Vinv3

Because only the faulty phase inverter output to be injected into the network, in Circuit is used in three Breaker, its order of the zero or one signal a switch to receive, Thus two-phase Breaker healthy, remain open and only the faulty phase Breaker is closed, and Voltage after passing through the filter, is injected by the transformer to the network. Each output of the inverter is shown in Figure 11. The end result of compensation single-phase voltage sag and swell is shown in Figure 12, 14. Regardless of the transient moments of beginning and end of depression, some ripple can be seen that, after reaching steady conditions, the circuit has been well compensated for depression. Figure 13,15 show the effective voltage before and after compensation.

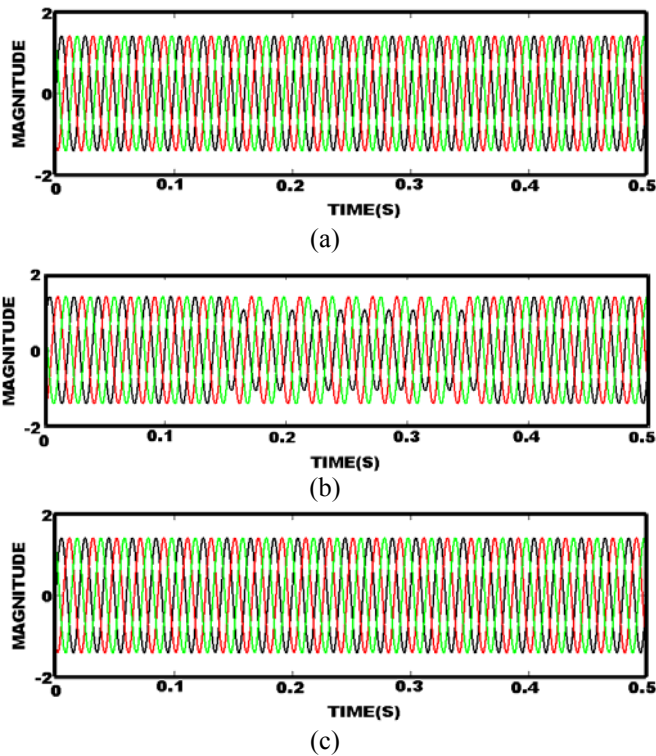


Figure 12. A single-phase voltage sag compensation results a) reference voltage b) before compensation c) after compensation

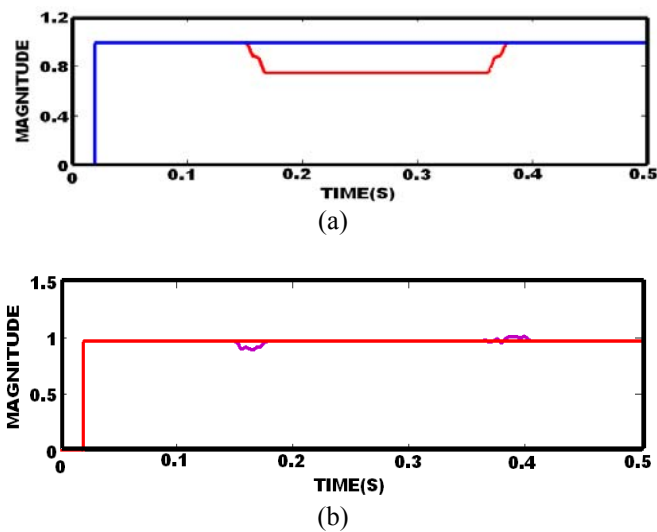


Figure 13. a) Before compensation b) after compensation

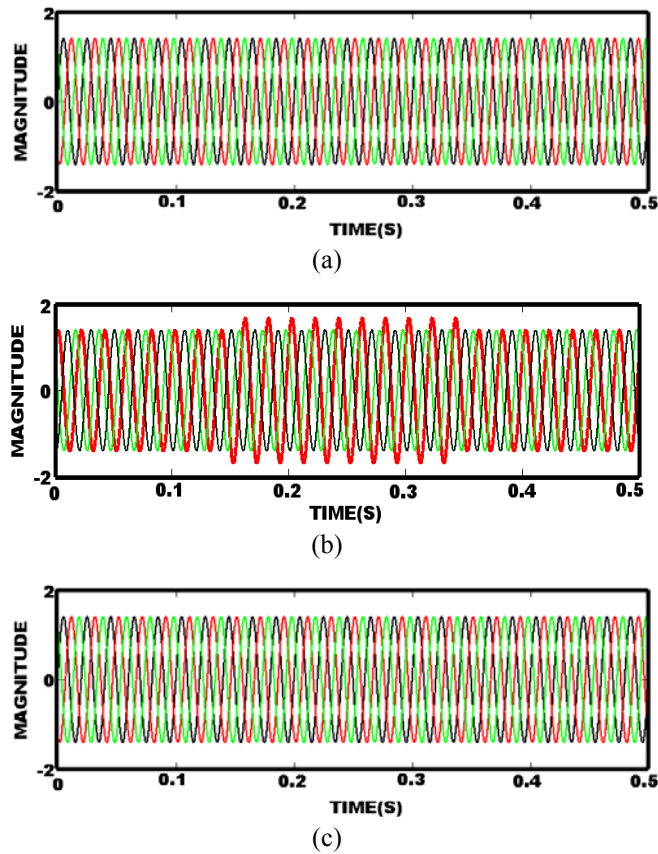


Figure 14. A single-phase voltage swell compensation results a) reference voltage, b) before compensation, c) after compensation

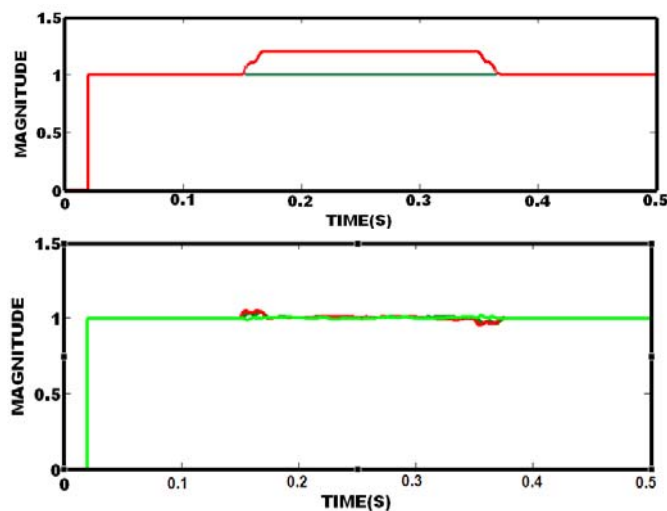


Figure 15. Voltage magnitude, a) before compensation, b) after compensation

5. CONCLUSION

Using series restorer near to sensitive loads is one the effective solution for restoring voltage sag. In this paper we could with modeling circuit for compensate single-phase sag, describe principles of performancethis compensatorsand obtain theexpected results.Also,we showedthatasmall changeinthecircuitcanalsocousesfromthecomensationvoltageswell. In design circuit for compensates single-phase sag, we usedthecomparison ofPUvalues. The resultsof the simulation, proper andexpected resultswillbe confirmedafterreachinga constantstate. But in the beginning and end of the transient moments of disturbance, (roughly the size of a cycle) results are not acceptable and will feel the need to further evaluate the circuit.

Detection of voltage sag in network is the first process for improvement of the power quality. Power quality problems contains wide spread range of voltage disturbance, because of various factors in this matter such as magnitude, frequency, balance detection and restoring is difficult. This variety makes impossible of using for unique algorithm. Series restorer which used in transmission and distribution systems is one of the functional method to improvement power quality problems, it is more economical when restorers are near to end user. Using DVR is one of the effective and economical methods for detecting and restoring of voltage sag and can restorer 90% voltage disturbances such as sag, swell and extra voltage, harmonic restorer voltage and asymmetrical voltage balancing systems, also has advantages as fast response, low losses conductivity and low switching.

REFERENCES

- [1] SeyyedHosseinHosseinian, ArifHello, "power quality," Tehran Regional ElectricCompany, First Edition, Spring1383.
- [2] N.L. Pérez, M.P. Donsión, "Technical Methods for the Prevention and Correction of Voltage Sags and Short Interruptions inside the Industrial Plants and in the Distribution Networks", International Conference on Renewable Energy and Power Quality (ICREPQ'03).
- [3] CH SRISAILAM, A SREENIVAS, "Mitigation Of Voltage Sags/Swells By Dynamic Voltage Restorer Using Pi And Fuzzy Logic Controller," International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 4, pp.1733-1737, July-August 2012.
- [4] Rosli Omar, N.A Rahim, "Implementation and Control of a Dynamic Voltage Restorer Using Space Vector Pulse Width Modulation (SVPWM) for Voltage Sag Mitigation".
- [5] R. Omar, N.A. Rahim, M. Sulaiman, "Modeling and Simulation for Voltage Sags/Swells Mitigation Using Dynamic Voltage Restorer (DVR)," Journal of Theoretical and Applied Information Technology, pp.464-470, 2005 - 2009 JATIT.
- [6] T.I. El-Shennawy, A.M. Moussa, M.A. El-Gammal, A.Y. Abou-Ghazala, "A Dynamic Voltage Restorer for Voltage Sag Mitigation in a Refinery with Induction Motors Loads," American J. of Engineering and Applied Sciences, pp. 144-151, 2010.
- [7] D.M. Lee, T.G. Habetler, R.G. Harley, T.L. Keister, J.R. Rostron, "A Voltage Sag Supporter Utilizing a PWM-Switched Autotransformer," IEEE Transactions on Power Electronics, Vol. 22, No. 2, March 2007.

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Mohammad Sarvi (Dr.) received his Bachelor in Electrical Engineering in 1998 from the Amirkabir Polytechnic University, and Master and PhD degrees in 2000 and 2004, respectively, from the Iran University of Science and Technology, Tehran, Iran. His research interest includes power electronics and Renewable Energy, FACTs and HVDC. Presently, Dr. Sarvi is an Assistant Professor at the Imam Khomeini International University, Qazvin, Iran.



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