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RESTORATION OF SUDDEN VOLTAGE SAGS OF A SENSITIVE LOAD IN A REAL NETWORK USING DVR

M. Farsadi [1]   J. Mostafapour [2,4]   E. Ogabi [3,4]

1. Electrical Engineering Department, Urmia University, Urmia, Iran, m_farsadi@urmia.ac.ir
2. Azarbaijan Regional Electric Company, Urmia, Iran, jafarmostafapour@yahoo.com
3. West Azarbaijan Electric Distribution Company, Urmia, Iran, ebrahem.1978@yahoo.com
4. West Azarbaijan Science and Research Unit, Urmia, Iran

Abstract- DVR is the apparatus that connects in series to the network and via injecting voltage into the system, regulates the load. This tool has capability of producing and absorbing active and reactive power. The DVR, usually places between sensitive load source and feeders in distribution system and its main task is quick strengthening of the voltage in load direction when abrupt changes occur. In this paper, we will investigate the effect of using DVR to compensate voltage sags of a sensitive load in the distribution system of West Azerbaijan province by using Matlab/Simulink.

Keywords: Voltage Sag, Dynamic Voltage Restorer (DVR), FACTS, STATCOM, VSC.

I. INTRODUCTION

In the past decade, there was a growth in the electrical equipment that has high sensitivity to the power quality. Major industrial consumers have reported many large economic losses due to the small drops of power quality. Therefore, there are a lot of attempts to prevent these losses. One of the newest solutions is using the technology of manufacturing power equipment to control power systems. A set of these equipment known as FACTS are being used to deal with problems of power distribution and continuity [1].

Today, there is wide range of flexible controllers which were manufactured by power equipment and are being used in power systems. Among them are Distribution Static Compensator (D-STATCOM) and Dynamic Voltage Restorer (DVR) that the latter is designed based on VSC and has attracted the most attention [1-4]. In this work, we have been used MATLAB software for modeling and analyzing of this controller for a sensitive load in West Azerbaijan's distribution network [5-7].

The advantage of this method is that, we only need to measure voltage and measuring reactive power is not needed [8-17]. In the case of DVR, the effects of occurring errors in system for a sensitive load in West Azerbaijan's distribution network and controlling voltage sag were simulated and analyzed.

II. INVESTIGATING THE PERFORMANCE OF DVR IN TRANSIENT STATE

Due to the relations of permanent performance of DVR, the control strategy of DVR in permanent state can be established. Now, in this section, we will establish the control strategy of transient state of DVR in two states of balance and imbalanced source.

A. When Source Is Balanced

The relations established for permanent state of source are based on the assumptions that, source or network is conventional. Although, this cannot be practical, but DVR voltage can be assumed only as the measurements of local voltages. Assuming that, the voltage of left side terminal of DVR that comes from source as V_t, we have:

$$\bar{V}_t = \bar{V}_l - \bar{V}_f = \bar{V}_l - \left|\bar{V}_f\right|\left(a_1 - jb_1\right) \tag{1}$$

Assuming $\bar{V}_l = \left|\bar{V}_L\right| < 0$, the following relation is obtained for injected DVR voltage:

$$\left|\bar{V}_f\right|^2 - 2\alpha_1\left|\bar{V}_t\right|.\left|\bar{V}_f\right| - \left|\bar{V}_l\right|^2 - \left|\bar{V}_f\right|^2 = 0 \tag{2}$$

Therefore, we have following control algorithm:

- The phase of system values will be locked on reference.
- The average half cycle value of positive component of current line will be established concerning the previous step.
- The value of range of $\left|\bar{V}_f\right|$ will be calculated from Equation (2).
- Finally, injected DVR voltage will be obtained from combination of range of $\left|\bar{V}_f\right|$ and angle of current line.

B. When the Source Is Imbalanced and Has Fluctuations

In this case, we can assume V_t as follows:

$$V_t = V_{tp} + V_{t-rest} \tag{3}$$

where, V_{tp} is the main component (positive) of terminal voltage and $V_{t\text{-}rest}$ is voltage shows the effects of imbalances and harmonics.

By Modifying Equation (2) we have:

$$\left|\bar{V}_{fp}\right|^2 - 2\alpha_1\left|\bar{V}_l\right|.\left|\bar{V}_{fp}\right| + \left|\bar{V}_l\right|^2 - \left|\bar{V}_{tp}\right|^2 = 0 \quad (4)$$

where, $\left|\bar{V}_{fp}\right|$ is the effective value of component and DVR voltage record. The DVR voltage can be obtained by solving the following equation after obtaining phases values of main and reference component.

$$V_f = V_{fp} + V_{f-rest} \quad (5)$$

Therefore, the positive component of voltage will be appropriately corrected and the harmonics resulted from V_t will be removed as well as zero or negative components of voltage. The results from analyzing show that the permanent performance of DVR is for compensating the sag voltage during injection power. In Figure 1, we consider the Thevenin of the network with the given DVR. According to the Figure 1, the DVR voltage is as follows:

$$V_{DVR} = V_L + Z_{th} I_L + V_{th} \quad (6)$$

The load's current I_L, is equal to:

$$I_L = \left[\frac{P_L + jQ_L}{V_L}\right] \quad (7)$$

If we assume load voltage, as zero, then the Equation (6) becomes:

$$V_{DVR}\angle\alpha = V_L\angle 0 + Z_{th} I\angle(\beta - \theta) - V_{th}\angle\delta \quad (8)$$

In the above equation α, β, and δ are the angles of V_{DVR}, Z_{th} and V_{th}, respectively and θ is the power angle of the load's power ($\theta = \tan^{-1}\frac{Q_L}{P_L}$). So, the nominal injected power of DVR is:

$$S_{DVR} = V_{DVR} I_L \quad (9)$$

The main application of DVR is compensating voltage sags. The DVR, is available for different applications with nominal capacities of 2-4 MVA, 660-880 KV of energy storage capacitor banks, and are being used to provide 0.3-0.5 per unit voltage at 300-500 milliseconds [8]. The advantage of DVR over D-STATCOM is protecting sensitive loads against voltage sags with low nominal values. In DVR, series transformers are designed at nominal values of current. However, the range of injected voltage by DVR is designed to compensate voltage sags to protect system. The nominal capacity of DVR (MVA) is calculated by $\text{MVA}_{\text{load}} \times \text{Injected Voltage (pu)}$.

As an example, a DVR with a capacity of almost 50% of sensitive load keeps the voltage at 0.9 per unit for 98% of voltage sags. Another attracting point about DVR is selecting required energy [8, 17]. Credible companies such as Mitsubishi, Siemens, ABB, and Toshiba are attempting to improve the quality of power with installing DVR and D-STATCOM.

C. Studied Sample

In order to show the impact of this controller in increasing voltage, simulation had been run in two stages of with and without DVR in time period (transient time) of 0.1 to 0.3 second on different phases. The 10% voltage drop and voltage increase without DVR is evident. The capacity of used capacitor was 800 micro farads and the coupling transformer with 0.9 leakage impedance was connected in triangle form in the side. Figures 9-13 show the sudden voltage sags at the connection point, r.m.s voltage changes of load, and the effect of DVR in time periods of 0.1 to 0.3 second for different configurations.

The capacity of DVR was selected around 50% of sensitive load. It is necessary to mention that, the loads connected to the 20 KV and 132 KV feeders of Pasan and Ghushchi, respectively, are as follows:

- Kaboudan Phosphate Co.: 3.4 MVA
- Zab San Co.: 4 MVA
- Zowb Ahan (steel plant) Co.: 5 MVA
- Urmia Sement Co.: 6 MVA

where, the sensitive load of Zob Ahan Co. has been selected. In Figures 2-14, two phase-ground fault in the system and its effective values are shown, respectively. The performance and action DVR for improving the given fault has been obtained.

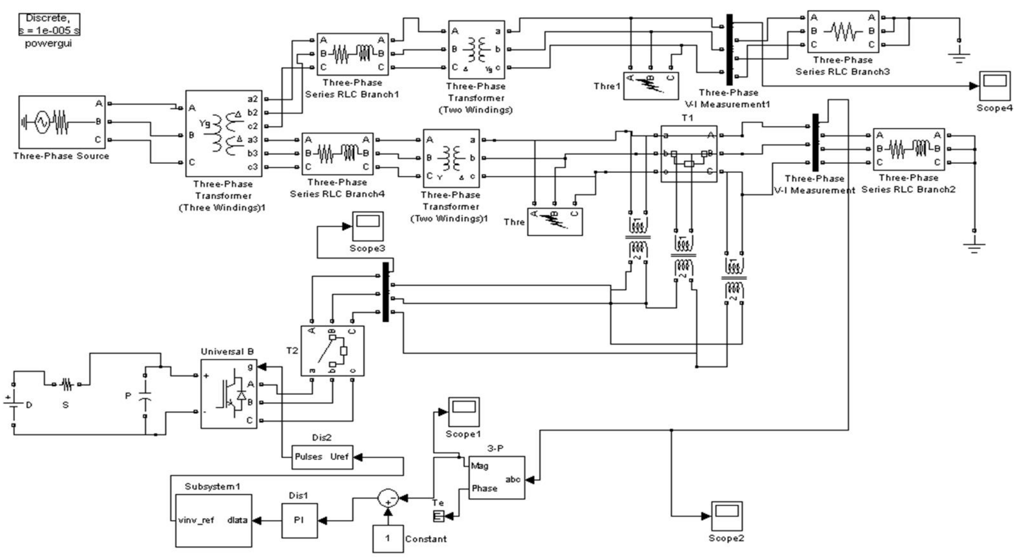

Figure 1. Simulation of the studied sample

III. RESULTS OF STUDIED SAMPLES USING MATLAB

This section shows all of the results that we have been obtained. The Figure 1 shows simulation of studied sample and Figure 2 shows equivalent circuit of distribution system. Figures 3-4 show two phase to ground error without DVR and correcting with DVR. Figure 5 shows correcting two phases to ground error with DVR which Figure 6 shows performance of DVR in correcting two phases to ground error with DVR.

Figure 7-8 show the effective value of two phases to ground without DVR and correcting the effective value of two phases to ground with DVR. Figure 9-10 show the effective value of three phases to ground voltage error without DVR and correcting the effective value of three phases to ground voltage error with DVR

Figures 11-12 show the error of one phase to ground in all three phases without DVR and correcting the error of one phase to ground in all three phases with DVR. Figures 13-14 show the effective value of one phase to ground voltage error without DVR, correcting effective value of one phase to ground voltage error with DVR.

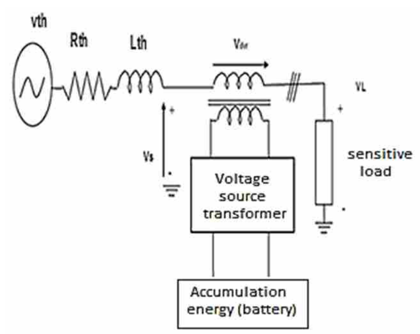

Figure 2. Equivalent circuit of distribution system

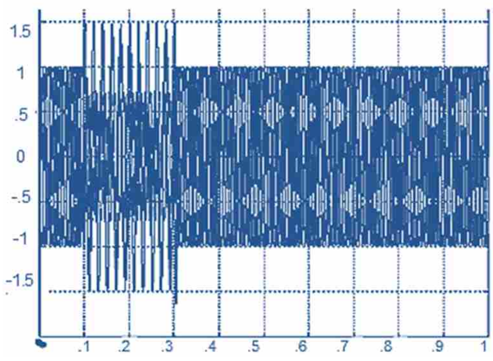

Figure 3. Two-phase to ground error without DVR

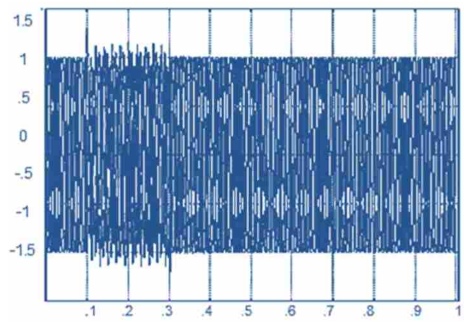

Figure 4. Correcting two-phase to ground error with DVR

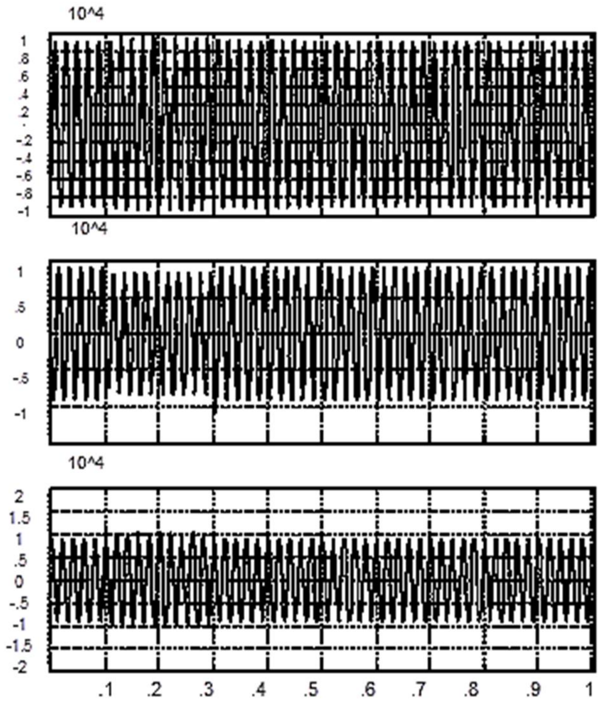

Figure 5. Correcting two-phase to ground error with DVR

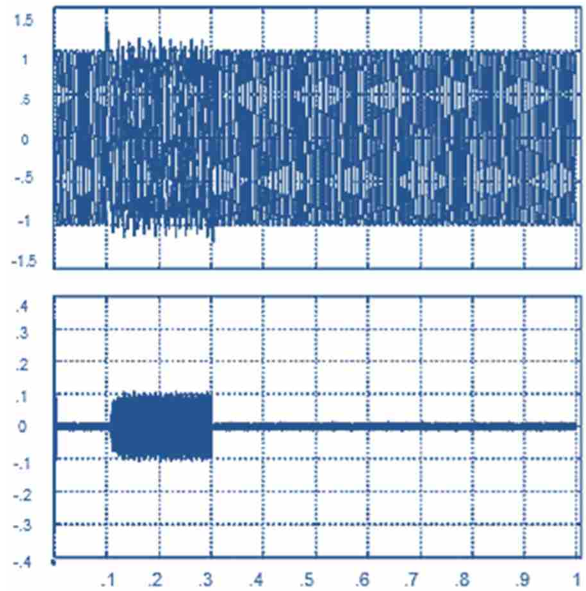

Figure 6. Performance of DVR in correcting two-phase to ground error with DVR

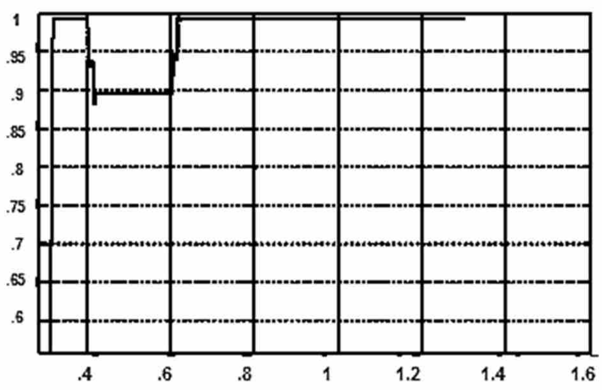

Figure 7. Effective value of two-phase to ground without DVR

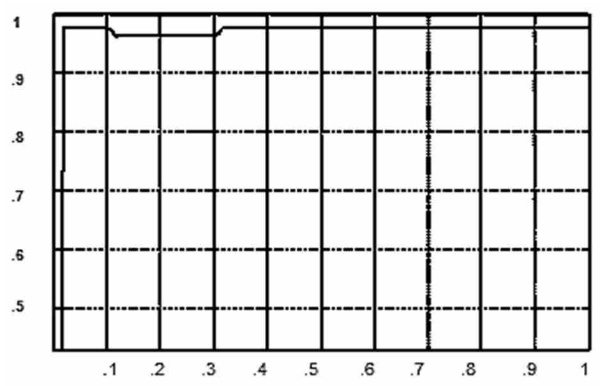

Figure 8. Correcting the effective value of two-phase to ground with DVR

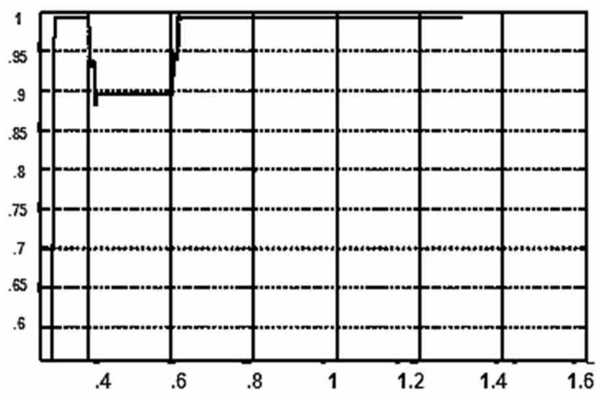

Figure 9. Effective value of three-phase to ground voltage error without DVR

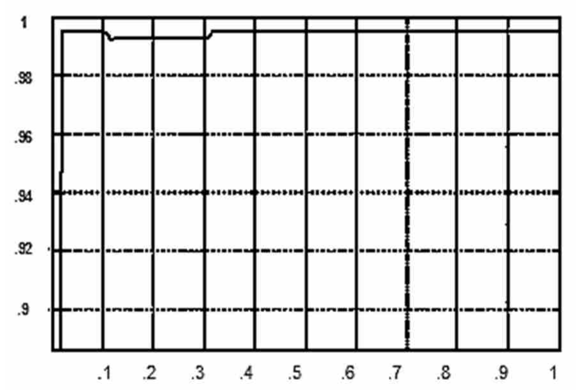

Figure 10. Correcting the effective value of three-phase to ground voltage error with DVR

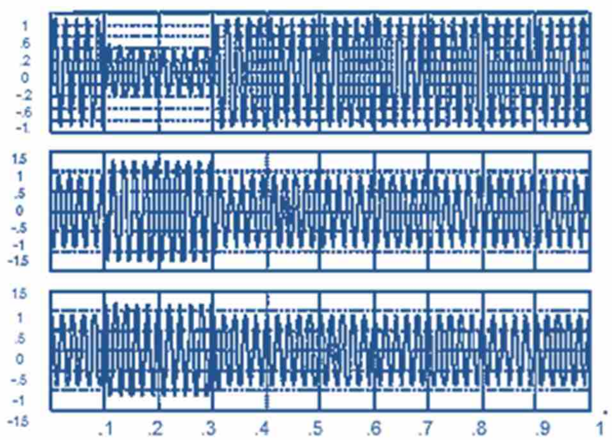

Figure 11. Error of one phase to ground in all three-phase without DVR

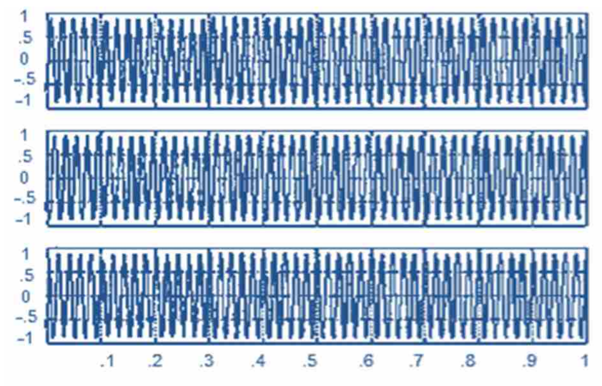

Figure 12. Correcting the error of one phase to ground in all Three-phase with DVR

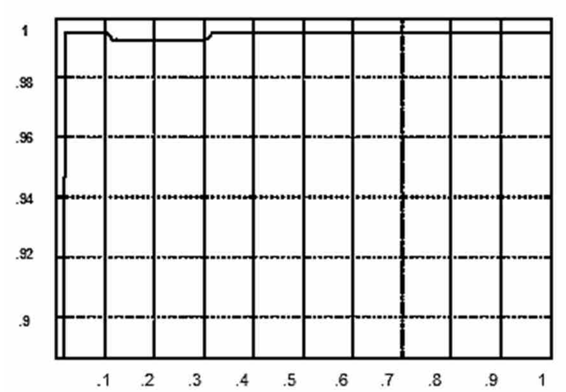

Figure 13. Effective value of one phase to ground voltage error without DVR

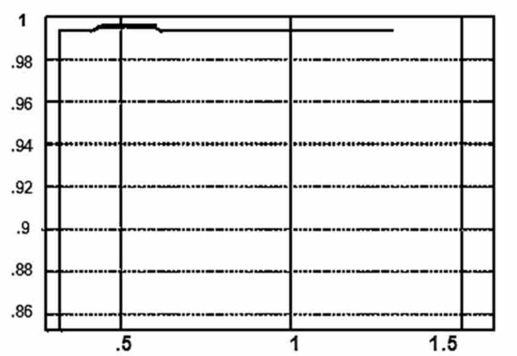

Figure 14. Correcting the effective value of one phase to ground voltage error with DVR

IV. CONCLUSIONS

The conducted simulation has shown that, DVR has a great capability to regulate voltage and can be used to improve the quality in sensitive loads. According to obtained results we can improve approximately 10% voltage drop in the system. So by using proper DVR, also we can increase the quality and quantity of system reactive power in the case of balance and in balance conditions during short periods.

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BIOGRAPHIES

Murtaza Farsadi was born in Khoy, Iran, in September 1957. He received his B.Sc. degree in Electrical Engineering, M.Sc. degree in Electrical and Electronics Engineering and Ph.D. degree in Electrical Engineering (High Voltage) from Middle East Technical University, Ankara, Turkey in 1982, 1984 and 1989, respectively. He is now an Assistant Professor in the Electrical Engineering Department, Urmia University, Urmia, Iran. His main research interests are in high voltage engineering, industrial power system studies and FACTS, HVDC transmission systems and DC/AC active power filters.

Jafar Mostafapour was born in Urmia, Iran, in 1974. He received the B.Sc. degree in Electrical Engineering in 2013. His research interests are in advanced power electronic and FACTS, partial discharge classification and localization in power transformers, fault location and HVDC transmission system and DC/AC active power filters.

Ebrahim Ogabi was born in Urmia, Iran, in1978. He received the B.Sc. degree in Electrical Engineering in 2013. His research interests are in advanced power electronic and FACTS, partial discharge classification and localization in power transformers, fault location and HVDC transmission system.