ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol3, Issue 5, May 2017

Performance Analysis of DVR Using Controller Parameter Optimization

[1] Manish KR.Pandey, [2] Dr.A.N.Tiwari
[1][2]Department of Electrical Engineering
MMM University of technology ,Gorakhpur, India

Abstract: **Dynamic Voltage Restorer is the accepted economical solution for safety of sensitive loads from voltage swell and sag. The DVR can provide active and reactive power. Inside DVR there is a control unit and it is the heart of the DVR where its function is to discern the presence of voltage sags in the system. In this paper we use a PI controller as the control unit of DVR. For designing of PI controller optimization algorithm known as Particle Swarm Optimization is used in this paper.**

Keyword: **Dynamic Voltage Restorer (DVR), Particle Swarm Optimization (PSO), Proportional Integral (PI) Controller.**

I. INTRODUCTION

Power quality is the major concern for power industry and customers. Power electronic equipments and nonlinear loads cause the problems in Power quality. Voltage swell, voltage sag and harmonics are the some dominant disturbances associated with electrical power.Due to these disturbances efficiency and life time of end user equipment decreases. Due to these disturbances memory loss and data loss in computer systems generally occurs.Power system network is very complex and due to this complex network voltage swell and voltage sag are main problems in power quality that directly affect the customer. They occur frequently and resulted in high loss in the system.The continuity of power supply can be maintained by clearing the faults at faster rate. Voltage transients, harmonics and voltage flickering are the power quality issue that has to be compensated to improve the power quality. The custom power electronic devices are recently helpful for voltage swell and voltage sag compensation. DVR comes under custom power device. The intent of this research is to design a PI Controller by different optimization techniques. Model of Dynamic voltage restorer (DVR) is used as plant. Modern heuristics method in functioning as Particle Swarm optimization (PSO) is employed for the enhancement and capability over the traditional techniques.[1]-[6]

II. DYNAMIC VOLTAGE RESTORER

In the last two decades number of sensitive equipments increases due to which importance of power quality increases. The disturbances in the system are mainly introduced by the nonlinear loads. Quality of more than 50% of the disturbances is of voltage type. Our main fascination is to study the deflection of voltage from its ideal curve. Main disturbances are harmonic and inter-harmonic voltages, voltage sags and swells for three phase systems. Custom Power devices are a new group of devices that are mainly positioned to improve quality of quality of power. Custom power electronic devices are split into three classes shunt connected compensator, series connected compensator and third type is that which is connected both in series and shunt. The compensator which is connected in series mainly consists of DVR. It is used to regulate the load terminal which is connected from low quality supply. DVR is used to protect consumer loads (which are critical) by loss and tripping. DVR mainly introduced to compensate for voltage disturbances on distribution system.

Due to big concentration of arc discharge lamps, speed drives and electric furnaces and other nonlinear equipments harmonics are generated. Iron and copper losses increases in electrical machines due to harmonic currents which are generated by nonlinear devices. Overheating and pulsating torques are produced in electrical machines due to harmonic currents.

When the short circuit fault occurs, voltage sag occurs in the power network. Voltage sag also caused when we starts the large rating induction motors. In electric motors reduction of energy transfer occurs due to adverse effect of voltage sag. Due to unbalanced short circuit faults or unbalanced loads, voltage imbalances occurs thus in synchronous machines overheating is produced.

For regulating the load side voltage DVR is used which is connected in series and it is a voltage source converter by which voltage can be injected into the system. When there is a power disturbance occurs on the load side then primary operation of the DVR is to upgrade the load side voltage.Its main work is voltage swells and sags compensation. DVR has other properties such as reduction in transients in voltage and fault current limitation and line voltage harmonic compensation. DVR made up of a voltage source inverter (VSI), an energy storage device, a voltage injection transformer and a control system.[7]

There are mainly five components for the modeling of the DVR

1.Voltage injection transformer
2. DC energy storage
3.Output filter
4. Voltage source inverter
5.Control system

Non-linearity in the DVR inverter model by the existence of semiconductor devices which works as switch in the bridge of inverter.

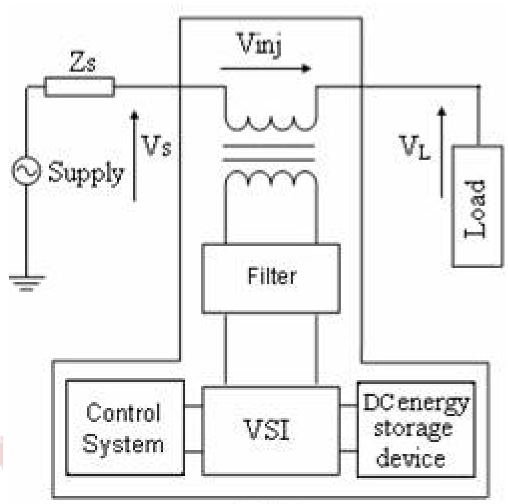

Figure1: Structure of DVR.

Control system design and modelling of dvr inverter Using the technique of state space averaging we can elaborate the performance of DVR in Difference or in the Differential form. LC filter and the loads that are attached are mostly used to outline the dynamic characteristics of the inverter [9]-[10].The attached loads may be non-linear, dynamic, linear static or their aggregate. To model a nonlinear load we may need a non-identical method. In our study the load is postulated as RL type linearity with an additional disturbance to present the dynamics of the load.Dynamic variance in the load may be detected by modeling the load in such a style and also it may be feasible to detect the action of the controller. In the Figure2 analogue single line diagram of inverter is presented where line impedance between supply voltage and DVR is assumed to be almost zero. State space form equations can be derived from this circuit diagram of figure 2.

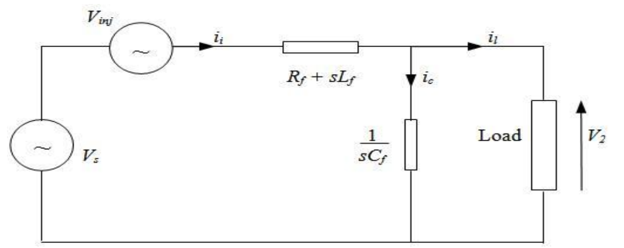

Figure2: DVR inverter equivalent circuit.

$$\begin{bmatrix} \frac{di_i}{dt} \\ \frac{dV_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R_f}{L_f} & -\frac{1}{L_f} \\ \frac{1}{C_f} & 0 \end{bmatrix} \begin{bmatrix} i_i \\ V_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{L_f} & 0 \\ 0 & -\frac{1}{C_f} \end{bmatrix} \begin{bmatrix} V_s \\ i_l \end{bmatrix} + \begin{bmatrix} \frac{1}{L_f} \\ 0 \end{bmatrix} \begin{bmatrix} V_{inj} \end{bmatrix}$$

Where inductor current in filter is i_i ,current in load is i_l , and injected voltage is V_{inj}. Figure2.5 presents the block diagram of open loop controller in a DVR inverter. The transfer functions of blocks $G_f(s)$, $G_c(s)$ and $G_l(s)$ are presented by the following expression

$$G_f(s) = \frac{1}{(R_f + s.L_f)},$$

$$G_l(s) = \frac{1}{(R_l + s.L_l)},$$

$$G_c(s) = \frac{1}{(s.C_f)}$$

The transfer function between input reference and load voltage is expressed as follows

$$G_{open}(s) = \frac{V_2(s)}{V_{ref}(s)} = \frac{k_i.(R_l + L_l.s)}{a.s^3 + b.s^2 + c.s + d}$$

Where

$$a = L_f.L_l.C_f$$

$$b = C_f.(R_l.L_f + L_l R_f),\quad c = L_l + L_f + C_f.R_f.R_l$$ and

$$d = R_f + R_l$$

Filter inductor current feedback in a close loop controller

In such type of control action inner feedback loop is established by the use of a feed- forward and filter inductor current loop is made up of input supply voltage and reference voltage. Dynamic performance such as steady state error and response time can be enhanced by this loop.

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol3, Issue 5, May 2017

Transfer functions are

$$G_{close}(s)=\frac{V_2(s)}{V_{ref}(s)}=\frac{(1+k_v.k_c).k_1.(R_l+L_l.s)}{a.s^3+b.s^2+c.s+d}$$

$$G_{close}(s)=\frac{V_2(s)}{V_{ref}(s)}=\frac{(1+k_v.k_c).k_1.(R_l+L_l.s)}{a.s^3+b.s^2+c.s+d}$$

Where,

$a=L_f.L_l.C_f$, $b=C_f.(R_l.L_f+L_l.R_f+k_c.k_1.L_l)$

$c=L_l+L_f+C_f.R_f.R_l+k_v.k_c.k_1.L_l+k_c.k_1.C_f.R_l$

Capacitor Current feedback in a controller

In this block diagram capacitor current i.e.The transfer function input voltage reference and load voltage is

$$G_{close}(s)=\frac{V_2(s)}{V_{ref}(s)}=\frac{(1+k_v.k_c).k_i.(R_l+L_l.s)}{a.s^3+b.s^2+c.s+d}$$

Where a, b, and c are identical in last section, but d is

$d=R_f+R_l+k_v.k_c.k_i.R_l$

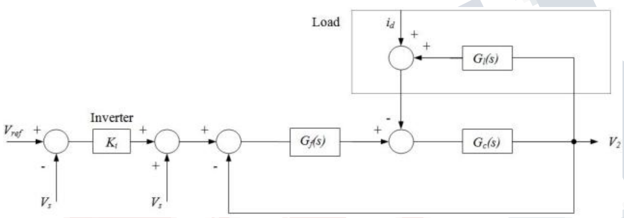

Figure3: DVR Inverter with open loop controller

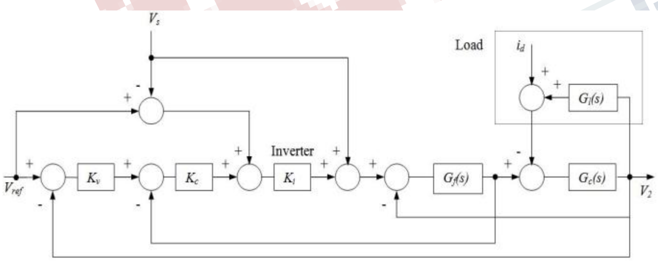

Figure4:Filter Inductor current feedback in a closed loop control system

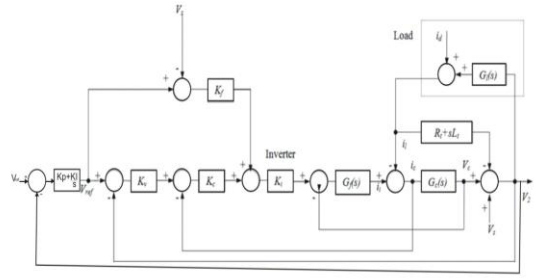

Figure5:Filter Inductor and Capacitorcurrent feedback in a closed loop control system

C. Aggregate of Filter Inductor and Capacitor Current Feedback in a Closed Loop Controller

Inductor current is directly associated to current at load , here capacitor current feedback is added to the portion of inductor, the performance of the system will more over be upgraded[22]-[23]. The transfer function is

$$\frac{V_2(s)}{V_{ref}(s)}=\frac{(1+k_vk_ck_f)k_1(R_l+L_ls)(k_ps+k_i)}{as^4+bs^3+cs^2+ds+(1+k_vk_ck_f)k_1(R_l+L_ls)(k_vs+k_i)}$$

Where

$a=L_lL_fC_f$,

$b=C_f(R_lL_f+L_lR_f+k_fk_1L_l+k_fk_1k_cL_l)$

$c=L_l+L_f+C_fR_fR_l+k_fk_1R_lC_f+k_fk_1k_cC_fR_l+k_vk_ck_fk_1L_l$

$d=R_f+R_l+k_vk_ck_fk_1R_l+k_fk_1$

The important aspect of the controller is to find out deflection in injected voltage and voltage sag by contributing proper switching strategies for the inverter.The important role of the controller is to detect the injected voltage deviation and voltage sag by providing appropriate switching strategies for the inverter. Controller input is an actuating signal which is the variance between voltage on the reference voltage and sensitive load. The range of switching frequency is in few KHz. Pulse width modulation (PWM) control system is applied for IGBT inverter switching so as to generate a three phase 50 Hz sinusoidal signals in order to maintain 1 PU voltage at the sensitive load terminal.

III. PARTICLE SWARM OPTIMIZATION(PSO)

A postulated algorithm will be placed when we requirethe conditions which are normal in nature. At these normal conditions we will tune the gains of PI controller for the optimal performance in the control system. PSO is

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol3, Issue 5, May 2017

applied for tuning of PI controller parameter when we need the model in offline mode. First of all a matrix is used for inserting the swarm particles which are initiated. Every particle presents a candidate's answer for the parameters of PI controller where there values can be in the span of 0-50 or bigger. Generally the range of value of PI Controller parameter set in the range of 0 to 100 where every particle constitutes a candidate solution for PI Controller parameter. This is a problem which is 3-dimensional in nature, where velocity and position are presented by matrices.3×Swarm size is the dimension of the matrices. Swarm size illustrate how much particles are there and generally it is generally attain as 50.Better response of the system is given by PI controller parameters which resulted in the optimization of index of performance. Generally optimization is taken as minimization of performance index.

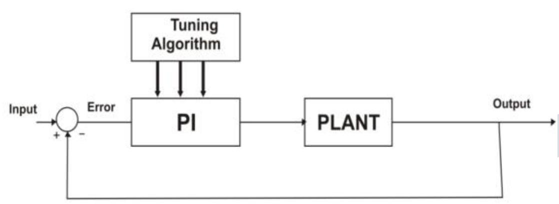

Figure 5: Tuning algorithm block diagram

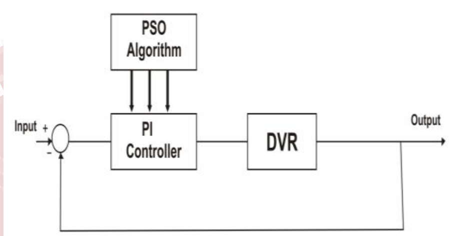

Figure 6: Block diagram of PSO with PI Controller

TABLE 1: PSO based simulation and result for Filter Inductor and Capacitor current feedback in a controller:

Iteration	kp	ki	Fitness
100	1.467	39.684	2.758
250	1.390	38.400	2.618
350	1.260	37.182	2.578
450	1.128	37.128	2.318
550	0.987	32.617	2.318
650	0.918	30.168	2.217
750	0.818	28.168	2.210
850	0.950	25.168	2.190
950	0.521	23.608	2.148
1000	0.058	20.189	2.009

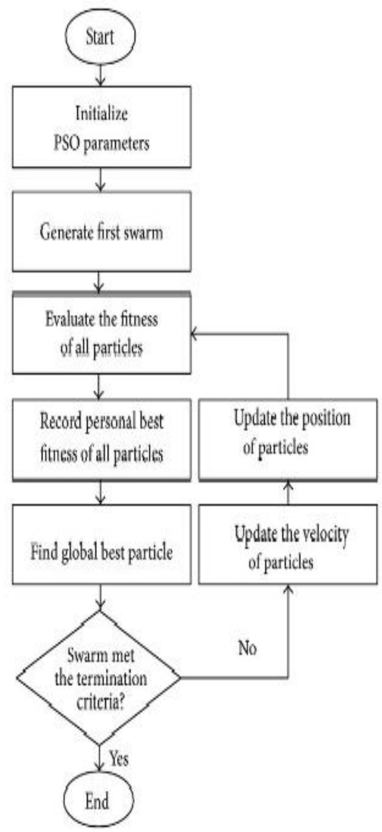

Figure7: Flow chart of PSO

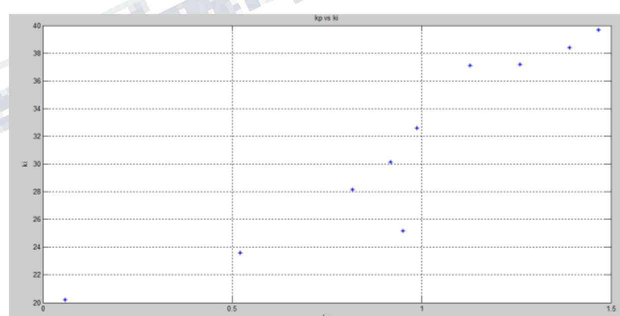

Figure 8: 2- Dimensional Graph of kp vs ki for filter Inductor and Capacitor Current Feedback

Simulation and results
System parameters are:
Filter inductance L_f= 6mH
Filter resistance R_f= *0.5 ohm*
Filter capacitance C_f = 31 microfarad
Load resistance R_l = 58 ohm
Load inductance L_l= 115mH

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol3, Issue 5, May 2017

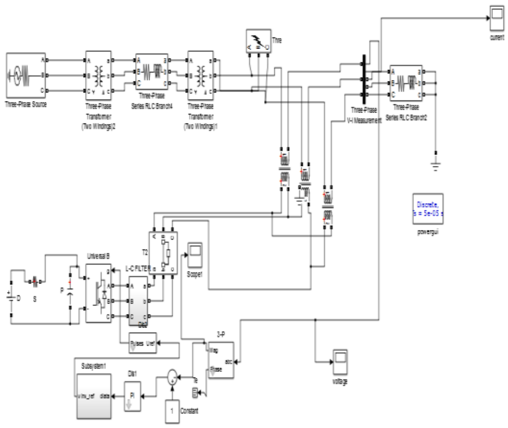

Figure 9:MATLAB Analysis of DVR for optimal values of PI Controller

For optimal designing number of iterations is 1000 and value of proportional gainand integral gain and value of fitness function are provided by the table 1.

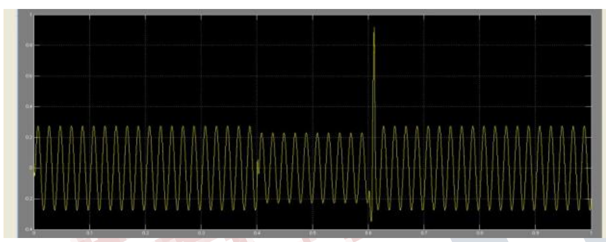

Figure 10:Voltage Sag during0.2 to 0.4 second

From Figure 10 we observe that voltage sag occurs in the system when DVR was not connected

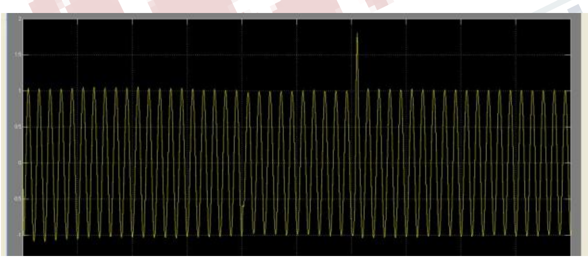

Figure11:Voltage Sag reduces when DVR is connected and 1 pu is achieved

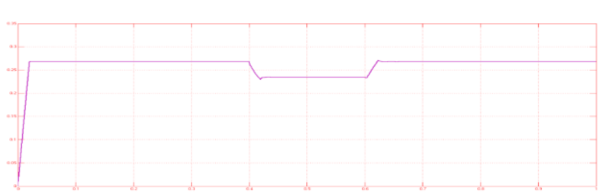

Figure 12: Fault occurs during 0.4 to 0.6 seconds when DVR was not connected

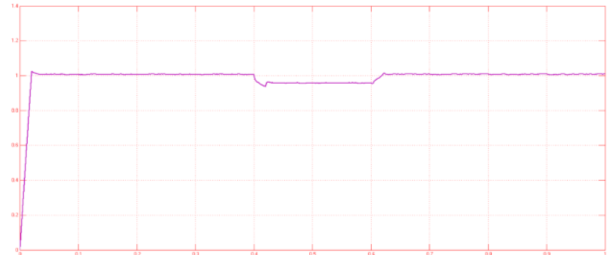

Figure 13: Fault reduces when DVR is connected

IV. CONCLUSION

From the analysis which are based on the result obtained it can be conclude that for designing of PI Controller Particle swarm Optimization gives better result than conventional algorithm. In case of PSO we have changed the number of iterations from 100 to 950 and further up to 1000. Performance of the system will improve when we will increase the iteration. For optimum value of parameters of PI controller we can remove the voltage sag and fault inside the DVR system.

REFERENCES

[1] Middlekauff S.W., Collins E.R.Jr.; "System and customer impact: Consideration for series custom power devices", IEEE Transactions on Power Delivery,1998, Vol.13, No.1, pp. 278–282.

[2] Woodley N.H., Morgan L., Sundaram A.; "Experience with an inverter-based dynamic voltage restorer", IEEE Transac-tions on Power Delivery, 1999, Vol.14, No.3 , pp. 1181–1186.

[3] Choi S.S., Li B.H., Vilathgamuwa D.M .; "Dynamic voltage restoration with minimum energy injection", IEEE Transac-tions on Power Systems, 2000, Vol.15, No.1,pp. 51–57.

[4] Li B.H., Choi S.S. ,Vilathgamuwa D.M .; "Design considera-tions on the line-side filter used in the dynamic voltage res-torer", IEE Generation, Transmission and Distribution, 2001, Vol.148, No.1, pp. 1-7.

[5] Vilathgamuwa D.M ., Perera A.A.D.R., Choi S.S.; "Voltage sag compensation with energy optimized dynamic voltage restorer", IEEE Transactions on Power Delivery, 2003, Vol.18, No.3, pp. 928–936.

[6] Vilathgamuwa D.M ., Wijekoon H.M .; "Control and analysis of a new dynamic voltage restorer circuit topology for miti-gating long duration voltage sags", 37th

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol3, Issue 5, May 2017

IAS Annual Meeting Industry Applications Conference, 2002, Vol. 2, pp. 1105-1112.

[6] Fitzer C., Barnes M ., Green P.; “Voltage sag detection tech-nique for a dynamic voltage restorer”, IEEE Transactions on Industry Applications, 2004, Vol.40, No.1, pp. 203–212.

[7] Prasai A., Divan D.M .; "Zero-energy sag correc-tors-optimizing dynamic voltage restorers for industrial ap-plications", IEEE Transactions on Industry Applications, 2008, Vol.44, No.6, pp. 1777 - 1784.

[8] Al-Hadidi H.K., Gole A.M ., Jacobson D.A.;" A novel con-figuration for a cascade inverter-based dynamic voltage res-torer with reduced energy storage requirements", IEEE Transactions on Power Delivery, 2008, Vol.23, No.2 , pp. 881–888.

[9] Al-Hadidi H.K., Gole A.M ., Jacobson D.A.;" Minimum power operation of cascade inverter-based dynamic voltage restorer", IEEE Transactions on Power Delivery, 2008, Vol.23, No.2 , pp. 889–898.

[10] Jimichi T., Fujita H., Akagi H.;" Design and experimentation of a dynamic voltage restorer capable of significantly reduc-ing an energy-storage element", IEEE Transactions on In-dustry Applications, 2008, Vol.44, No.3, pp. 817 - 825.

[11] Jowder F.A.L.;" Design and analysis of dynamic voltage restorer for deep voltage sag and harmonic compensation", IET Generation, Transmission and Distribution, 2009, Vol.3, No.6, pp. 547 – 560.

[12] Hyosung Kim, Seung-Ki Sul;"Compensation voltage control in dynamic voltage restorers by use of feed forward and state feedback scheme", IEEE Transactions on Power Electronics, 2005, Vol. 20, No.5, pp. 1169 – 1177.

[13] Li G.J., Zhang X.P., Choi S.S., Lie T.T., Sun Y.Z.;" Control strategy for dynamic voltage restorers to achieve minimum power injection without introducing sudden phase shift", IET Generation, Transmission and Distribution, 2007, Vol.1, No.5, pp. 847 – 853.

[14] Yun Wei Li; Vilathgamuwa D.M ., Blaabjerg F., Poh Chiang Loh;" A robust control scheme for medium-voltage-level DVR implementation", IEEE Transactions on Industrial Electronics, 2007, Vol.54, No.4, pp. 2249 – 2261.

[15] Meyer C., De Doncker R.W., Yun Wei Li, Blaabjerg F.; "Optimized control strategy for a medium-voltage DVR-theoretical investigations and experimental results", IEEE Transactions on Power Electronics, 2008, Vol. 23, No.6, pp. 2746 - 2754.

[16] Roncero-Sanchez P., Acha E., Ortega-Calderon J.E., Feliu V., Garcia-Cerrada A.;" A versatile control scheme for a dynamic voltage restorer for power-quality improvement", IEEE Transactions on Power Delivery, 2009, Vol.24, No.1 , pp. 277 - 284.

[17] Bae B., Lee J., Jeong J., Han B.;" Line-interactive sin-gle-phase dynamic voltage restorer with novel sag detection algorithm", IEEE Transactions on Power Delivery, 2010, Vol.25, No.4 , pp. 2702 - 2709.

[18] Bae B., Jeong J., Lee J., Han B.;" Novel sag detection method for line-interactive dynamic voltage restorer", IEEE Trans actions on Power Delivery, 2010, Vol.25, No.2 , pp. 1210 - 1211.

[19] Ho C.N.-M .; Chung H.S.-H.;" Implementation and perfor-mance evaluation of a fast dynamic control scheme for capa-citor-supported interline DVR", IEEE Transactions on Power Electronics, 2010, Vol. 25, No.8, pp. 1975 - 1988.

[20] Yun Wei Li, Poh Chiang Loh, Blaabjerg F., Vilathgamuwa D.M .; "Investigation and improvement of transient response of DVR at medium voltage level", IEEE Transactions on Industry Applications, 2007, Vol.43, No.5, pp. 1309 - 1319.

[21] Moradlou M ., Karshenas H.R.;" Design strategy for optimumrating selection of interline DVR", IEEE Transactions on Power Delivery, 2011, Vol.26, No.1 , pp. 242 - 249.

[23] Mahdianpoor F.M ., Hooshmand R.A., Ataei M .;" A new approach to multifunctional dynamic voltage restorer im-plementation for emergency control in distribution systems", IEEE Transactions on Power Delivery, 2011, Vol.26, No.2 , pp. 882 - 890.

[24] Newman M .J., Holmes D.G., Nielsen J.G., Blaabjerg F.;" A dynamic voltage restorer (DVR) with selective harmonic compensation at medium voltage level", IEEE Transactions on Industry Applications, 2005, Vol.41, No.6, pp. 1744 – 1753.