OPERATION AND CONTROL OF CASCADED H-BRIDGE-BASED INTERLINE DYNAMIC VOLTAGE RESTORER IN DISTRIBUTION SYSTEM

N.Nagalakshmi[1] | M.Swathi[2] | M.L.Dwarakanand[3]

[1](M.Tech Scholar, Dept of EEE, Global College of Engineering & Technology, Kadapa, A.P, India)
[2](Asst. Professor, Dept of EEE, Global College of Engineering & Technology, Kadapa, A.P, India)
[3](Asso. Professor, Dept of EEE, Global College of Engineering & Technology, Kadapa, A.P, India)

Abstract— *An interline dynamic voltage restorer (IDVR) is a new device for sag mitigation which is made of several dynamic voltage restorers (DVRs) with a common dc link, where each DVR is connected in series with a distribution feeder. During the sag period, active power can be transferred from a feeder to another one and voltage sags with long durations can be mitigated. IDVR compensation capacity, however, depends greatly on the load power factor, and a higher load power factor causes lower performance of IDVR. To overcome this limitation, a new idea is presented in this paper which enables reducing the load power factor under sag conditions and, therefore, the compensation capacity is increased. The proposed IDVR employs two cascaded H-bridge multilevel converters to inject ac voltage with lower total harmonic distortion and eliminates the necessity to low-frequency isolation transformers in one side. Then, experimental results on a scaled-down IDVR are presented to confirm the simulation results.*

Keywords— Back-to-back Converter; Cascaded H-bridge; Interline Dynamic Voltage Restorer (IDVR); Minimum Energy; Power Quality (PQ); Voltage Sag

1. INTRODUCTION

Modern power systems are complex networks, where several producing stations and a great many load focuses are interconnected through long power transmission and dissemination systems. The primary worry of buyers is the quality and unwavering quality of energy supplies at different load focuses where they are found. Despite the fact that power era in the greater part of the very much created nations is genuinely dependable, the nature of the supply is not all that solid. Power dissemination frameworks, in a perfect world, ought to furnish their clients with a continuous stream of vitality at smooth sinusoidal voltage at the contracted extent level and recurrence. Be that as it may, by and by, control frameworks, particularly the circulation frameworks, have various nonlinear burdens, which altogether influence the nature of energy supplies. Because of the nonlinear burdens, the immaculateness of the waveform of provisions is lost. This winds up delivering many power quality issues. Aside from nonlinear burdens, some framework occasions, both common (capacitor exchanging, engine beginning) and surprising (shortcomings) could likewise perpetrate control quality issues. A power quality issue is characterized as any showed issue in voltage/present or prompting recurrence deviations that outcome in disappointment or mis-operation of client hardware. Contingent upon the electrical separation identified with impedance, the sort of establishing and association of transformers between the blamed/stack area and the hub, there can be an impermanent loss of voltage or brief voltage decrease (hang) or voltage rise (swell) at various hubs of the framework. Among the few novel custom power gadgets, the DVR is the most in fact progressed and temperate gadget for voltage hang moderation in dissemination frameworks. The regular DVR works by infusing AC voltages in arrangement with the approaching three-stage organize, the motivation behind which is to enhance voltage quality by an alteration in the voltage greatness, wave shape and stage move. The voltage hang pay includes the infusion of genuine and responsive energy to the dissemination framework. The receptive power prerequisite can be produced electronically inside the voltage source inverter of the DVR. The Voltage Source Inverter (VSI) topology is predominantly utilized as a part of a customary DVR, as it gives great yield voltage with low symphonious levels. The principle impediment of this topology is its buck sort yield voltage trademark, constraining the greatest voltage that can be accomplished. This implies the DVR infusion ability would be constrained, particularly when the DC connect voltage dips under a specific basic esteem. Accordingly, the utilization of this inverter topology alone in DVR frameworks with decreasing DC connect voltage in the vitality stockpiling gadget, would represent an issue. A large portion of the applications would require the inverters to have both voltage buck and lift abilities, for riding through load current and supply voltage varieties. To conquer the above issues of the conventional VSI and Current Source Inverter (CSI), an Impedance Source Inverter (Z Source Inverter) is displayed. Z source inverters have been accounted for as of late as focused other options to existing inverter topologies with numerous innate preferences. The Z source inverter contrasts from customary converters like the VSI and CSI because of the nearness of an interesting X-formed impedance organize on its DC side, which interfaces the source and the inverter H-connect. It encourages both voltage-buck and lift capacities.

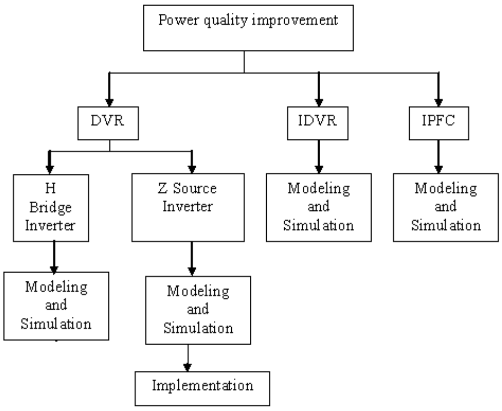

Figure 1- Tree diagram

It utilizes a one of a kind impedance system to couple the converter primary circuit to the power source, stack or another converter, for giving one of a kind components that can't be seen in the customary VSI and CSI, where a capacitor and inductor are utilized individually. The Z source inverter gives a novel power transformation idea. The Interline Dynamic Voltage Restorer (IDVR) gives an approach to renew the vitality in the regular DC connect vitality stockpiling progressively. The IDVR framework comprises of a few DVRs securing touchy loads in various circulation feeders radiating from various network substations, and these DVRs share a typical DC connect. The group of Voltage Source Converter (VSC) based FACTS gadgets involves the Static Synchronous Compensator (STATCOM), the static Synchronous Series Compensator (SSSC), the Unified Power Flow Controller (UPFC) and the Interline Power Flow Controller (IPFC). The UPFC is utilized as a capable apparatus for the financially savvy use of individual transmission lines by encouraging the autonomous control both the genuine and responsive power stream. While, the IPFC idea gives an answer for the issue of repaying various transmission lines at a given substation. Any inverters inside the IPFC can exchange genuine energy to some other and accordingly encourage genuine power exchange among the lines, together with autonomously controllable responsive arrangement pay of every individual line. The IPFC tends to the issue of repaying various lines at a given substation. The IDVR plot gives an approach to exchange genuine power between touchy loads in an individual line through the regular DC connection of the DVRs, as it does in the IPFC. Be that as it may, the lines in the IPFC begin from a solitary network substation, while the lines in the IDVR framework start from various lattice substations.

2. VOLTAGE SAG

2.1 INTRODUCTION

Voltage sag as described by IEEE Standard 1159-1995, IEEE suggested carryout for Monitoring Electric Power Quality, as a reduce in voltage of RMS at the power frequency of span from 0.5 cycles to 1 minute, conveyed as the residual voltage.

The measurement of voltage sag is affirmed as a proportion of the supposed voltage; it is a dimension of the residual voltage and is affirmed as sag to a fraction value. Hence a voltage sag to 60% is equivalent to 60% of supposed voltage, otherwise 288 volts for a nominal 480 Volt system.

2.2 CAUSES OF VOLTAGE SAGS

A. OPERATION OF RE-CLOSERS AND CIRCUIT BREAKERS

But, for any reason, a re-closer or a sub-station circuit breaker is tripped, subsequently the line so as to it is supply will be temporarily detached. All other feeder lines as of the same substation system will saw this detachment event as voltage sag which will expand to consumers on these other lines. The intensity of the sag of voltage at the customer's location will vary depending on the line voltage supply and the remoteness from the error due to fault. In general, a superior voltage supply can have a larger sag influenced zone.

B. SINGLE-PHASE SAGS AND MULTI-PHASE SAGS

- *Single-Phase Sags*

The most frequent sags of voltage, above 70%, are of single-phase actions which are characteristically owing to a fault of phase-to-ground occurring someplace on the arrangement. This fault due to phase-to-ground appears as voltage sag of single phase on further feeders from the unchanged substation. Usually sources are contact of animal, strikes of lightning, tree branches, etc. It is not infrequent for seeing the voltage sags of single phase to 30% of supposed voltage or yet inferior in industrialized systems.

- *Phase-to-Phase Sags*

Phase-to-phase, Two-phase sags might be caused by adverse weather, animals, and branches of tree or collision of vehicle with poles of utility. The voltage sag of two-phase will naturally seem on additional feeders commencing the identical substation.

- *Phase Sags*

Symmetrical three-phase sags report for fewer than 20% of all the sag measures as well as are origin

$$\underline{U}_{sec} = \underline{P}\,\underline{A}\,\underline{P}^{-1}\underline{U}_{pri}$$

either by tripping or switching of a three-phase circuit breaker, re-closer or switch which will create a voltage sag of three-phase on additional lines fed from the similar substation. Sags of Three-phase may also be resulted by initializing heavy motors, except this kind of incident normally results voltage sags to roughly 80% of supposed voltage and are typically restricted to an industrialized plant or its instantaneous neighbor.

C. SAG PROPAGATION

Although most consumers are linked to LV networks, faults take place at all voltage levels.

Therefore, the sag transmission during the complete power system must be designed. The fault category, earthing practices, and transformer links resolve which voltages are of concern when captivating into description sags at the location of LV customer. In this project, the Finnish power collection is used as an occurrence to terminate the voltage sag distributions accomplished by LV customers, that is:

i. 400 and 220 kV systems of transmission, looped, impedance neutrals earthed, or steadily earthed;
ii. 110 kV sub-transmission system; looped, neutrals impedance earthed, or unearthed;
iii. Medium voltage of 20 kV, operated radially, unearthed neutral, or remunerated;
iv. 0.4 kV low voltages, radially operated, solidly earthed. Linking of distinctive transformers;
v. 400/110 kV, 400/220 kV, 220/110 kV: YNyn0d11 (d11, typically 21 kV, is used for recompense);
vi. 110/20 kV: YNd11;
vii. 20/0.4 kV: Dyn11.

Y denotes wye connected, d denotes delta connected, and n denotes neutral earthed systems. Capitals denote primary side and small letters denotes transformer secondary side.

Sags caused by balanced 3-phase faults promulgate without changes throughout transformers. In the case of asymmetrical faults, on the other hand, the transformer connections have a burly effect. The secondary side phase voltages U_{sec} are substantial from the primary side phase voltages U_{pri} as follows:

$$\underline{P} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \underline{a}^2 & \underline{a} \\ 1 & \underline{a} & \underline{a}^2 \end{bmatrix}$$

$$\underline{A} = \begin{bmatrix} \underline{A}(1,1) & 0 & 0 \\ 0 & 1\angle\alpha & 0 \\ 0 & 0 & 1\angle-\alpha \end{bmatrix}.$$

In matrix P^{-1} transforms the phase voltages to symmetrical works, whereas matrix P does the nullifying. Matrix determines the transformer category. The part depends on how the zero sequence components circulate throughout the transformer.

When the current of zero order may not approach apart in both the windings, then A(1,1) is place to 0. In a YN-YN transformer through both earthed neutrals, A (1, 1) =1. Angle α is resolute by alteration in the positive sequence voltage.

3. PROPOSED SYSTEM

A simple IDVR which is shown in Fig. 3.1 consists of two back-to-back voltage-source converters (VSC) with a common dc link. By using this topology, it is possible to transfer active power from a feeder to another one during the sag condition and to mitigate deeper and longer voltage sags (Fig. 3.1).

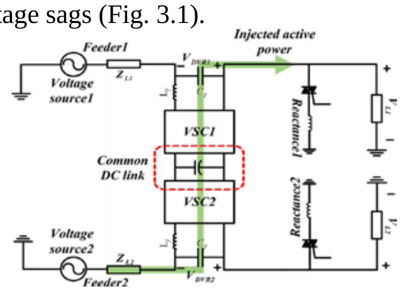

Fig. 3.1. Power circuit schematic of the IDVR with active power-exchanging capability.

Consider, for example, the condition in which voltage sag occurs in feeder1 and DVR1 starts to compensate it. To overcome this problem and to improve IDVR performance, the load power factor has to be decreased at the sag period. The remaining question is how to achieve this goal if the load power factor is higher than the expected value. To resolve this issue, a thyristor-switched fixed value reactance is paralleled to each load.

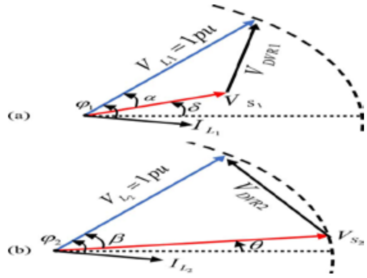

Fig. 3.2. Phasor diagram of the IDVR during voltage sag compensation: (a) DVR1 injected voltage and (b) DVR2 injected voltage.

Using this reactance, one can decrease the load power factor when it is needed. In other words, when the IDVR capacity is not enough for compensation, the shunt reactances are added to the circuit. Otherwise, they are not employed in the compensation period. Moreover, active power, which is drawn by DVR2 from feeder2 can be derived from Fig. 3.2.

According to the aforementioned assumptions, the effect of load power factor on the IDVR performance is obtained and demonstrated in Fig. 3.3. It is observed that the ohmic loads cannot be compensated completely by the IDVR because no exists for these conditions. However, for loads with a lower power factor, IDVR can mitigate larger sags. For example, when the load power factor is 0.5, IDVR can compensate the entire range of voltage sags by choosing appropriate.

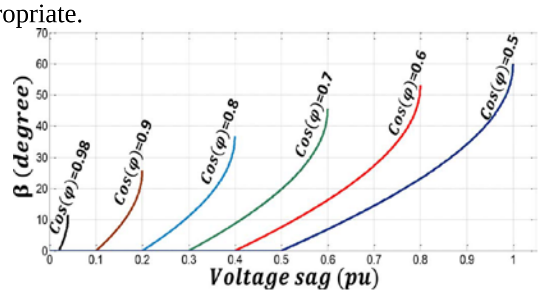

Fig. 3.3. Effect of load power factor on the performance of IDVR.

In other words, when feeder1 drops completely (or voltage sag amplitude is 1 p.u.), IDVR can compensate it completely if the load power factor is 0.5. Fig. 5.4 illustrates the improvement of IDVR compensation capability in the presence of shunt reactances. It is seen that by applying the shunt reactances and decreasing the power factor from 0.98 to 0.8, the depth of compensation increases from 0.04 to 0.4 p.u. (A & B points).

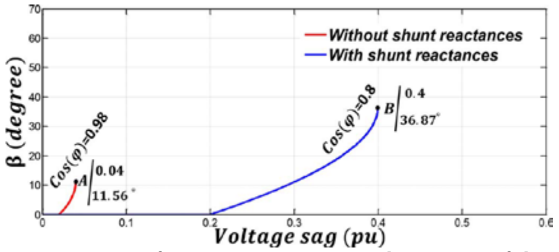

Fig. 3.4. IDVR performance improvement in the presence of shunt reactances.

Fig. 3.5 shows a comparison between the compensation capability of two separate DVRs and an IDVR for different ratios. The first topology consists of two independent DVRs installed on feeder1 and feeder2 with capacitive dc links.

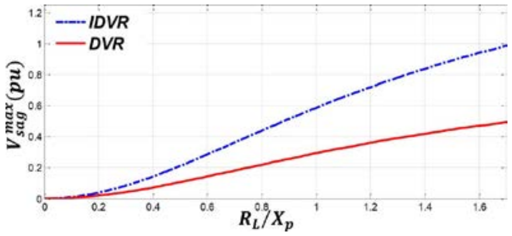

Fig. 3.5. Comparing the compensation capability of DVR and IDVR.

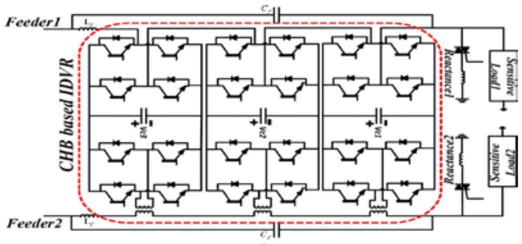

Fig. 3.6. Proposed IDVR structure.

Fig. 3.6 demonstrates a single-phase 7-level CHB-based IDVR which is used in the simulation study and experimental investigation. Although a 7-level back-to-back converter is chosen for the study in this paper, the proposed control strategy can be applied to any number of voltage levels and there is no limitation from this point of view. In other words, the generated voltage references by the control system will be synthesized by the CHB converter through well-known multilevel modulation techniques. The only issue is related to keeping voltage balance among dc-link capacitors which has been addressed for any number of voltage levels.

4. SIMULATION RESULTS

To investigate the system performance in voltage sag compensation, several simulations have been done in the matlab/simulink environment on a single-phase IDVR.

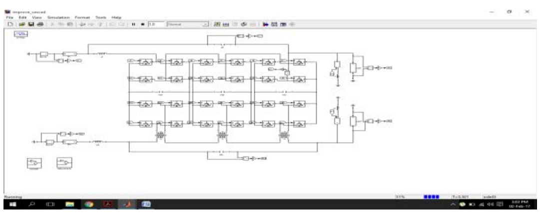

Fig:4.1 simulation circuit diagram of proposed system

In these simulations, two shunt reactances are used for power factor reduction during the sag periods. By adding the shunt reactances, the dc-current component may occur; however, if the shunt reactance is switched on at near the peak of the voltage, this component will be significantly small.

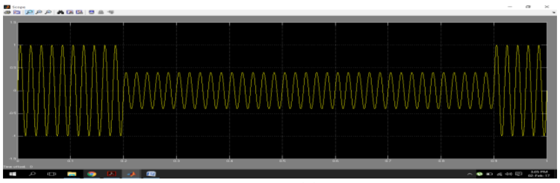

Fig:4.2(a)

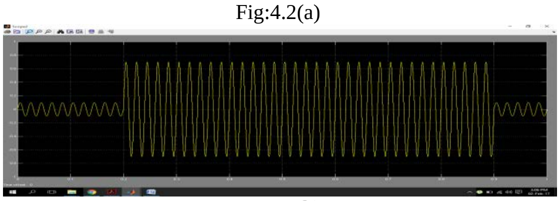

Fig:4.2(b)

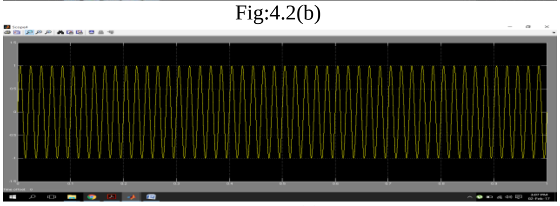

Fig:4.2(c)

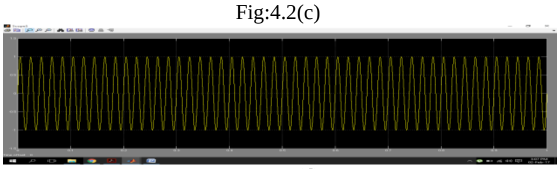

Fig:4.2(d)

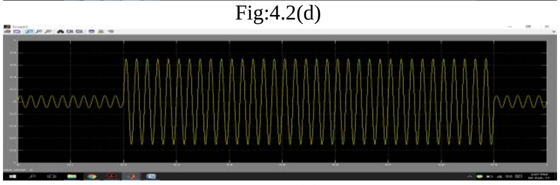

Fig:4.2(e)

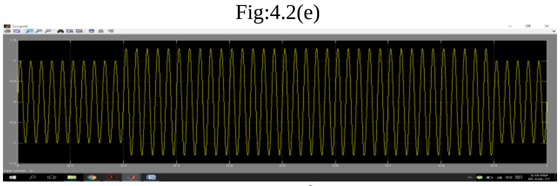

Fig:4.2(f)

Fig. 4.2. Investigating the IDVR performance when the proposed method is applied for a sag with a depth of 0.4 p.u.

In this study, a sag with a depth of 0.4 p.u. occurs on source1 at 0.3 s. As was already mentioned, at high power factors, the ordinary IDVR is not able to mitigate these kinds of voltage sags. However, after inserting the shunt reactances and reducing the load power factors from 0.98 to 0.8, the IDVR can compensate this voltage sag completely as can be seen.

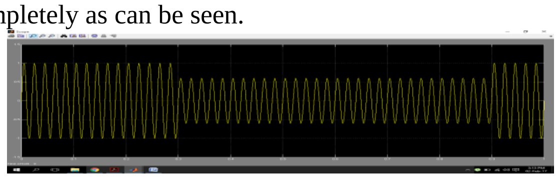

Fig:4.3(a)

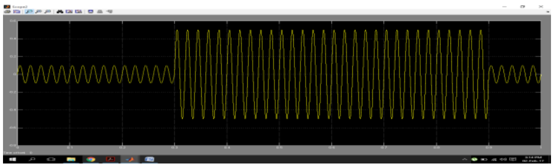
Fig:4.3(b)

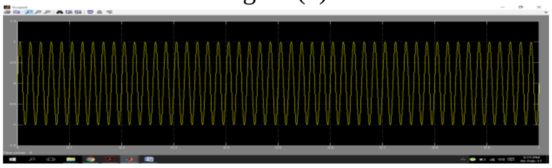
Fig:4.3(c)

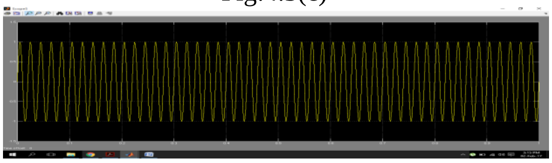
Fig:4.3(d)

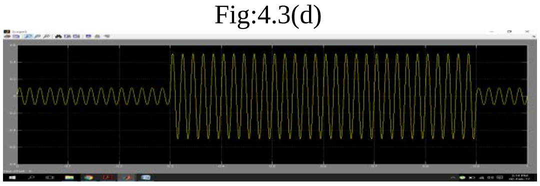
Fig:4.3(e)

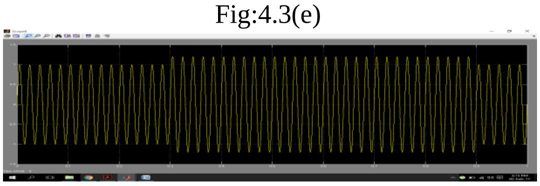
Fig:4.3(f)

Fig. 4.3. Investigating the IDVR performance when the proposed method is applied for a sag with a depth of 0.6 p.u.

In this part, the power factors of both loads are reduced from 0.8 to 0.7 during the sag condition. According at this condition, the IDVR can compensate the voltage sags with the maximum depth of 0.6 p.u. illustrates the IDVR operating principle when the proposed configuration is employed. It can be seen that the IDVR can successfully compensate the voltage sag and keep the load voltage at 1 p.u.

5. CONCLUSION

In this paper, a new configuration has been proposed which not only improves the compensation capacity of the IDVR at high power factors, but also increases the performance of the compensator to mitigate deep sags at fairly moderate power factors. These advantages were achieved by decreasing the load power factor during the sag condition. In this technique, the source voltages are sensed continuously and when the voltage sag is detected, the shunt reactances are switched into the circuit and decrease the load power factors to improve IDVR performance. Finally, the simulation and practical results on the CHB-based IDVR confirmed the effectiveness of the proposed configuration and control scheme.

REFERENCES

[1] P. F. Comesana, D. F. Freijedo, J. D. Gandoy, O. Lopez, A. G. Yepes, and J. Malvar, “Mitigation of voltage sags, imbalances and harmonics in sensitive industrial loads by means of a series power line conditioner,” Elect. Power Syst. Res., vol. 84, pp. 20–30, 2012.

[2] A. Felce, S. A. C. A. Inelectra, G. Matas, and Y. Da Silva, “Voltage sag analysis and solution for an industrial plant with embedded induction motors,” in Proc. IEEE Ind. Appl. Soc. Conf. Annu. Meeting., 2004, vol. 4, pp. 2573–2578.

[3] A. Sannino, M. G. Miller, and M. H. J. Bollen, “Overview of voltage sag mitigation,” in Proc. IEEE Power Eng. Soc. Winter Meeting, 2000, vol. 4, pp. 2872–2878.

[4] E. Babaei, M. F. Kangarlu, and M. Sabahi, “Mitigation of voltage disturbances using dynamic voltage restorer based on direct converters,” IEEE Trans. Power Del., vol. 25, no. 4, pp. 2676–2683, Oct. 2010.

[5] H. K. Al-Hadidi, A. M. Gole, and D. A. Jacobson, “A novel configuration for a cascade inverter-based dynamic voltage restorer with reduced energy storage requirements,” IEEE Trans. Power Del., vol. 23, no. 2, pp. 881–888, Apr. 2008.

[6] D. M. Vilathgamuwa, A. A. D. R. Perera, and S. S. Choi, “Voltage sag compensation with energy optimized dynamic voltage restorer,” IEEE Trans. Power Del., vol. 18, no. 3, pp. 928–936, Jul. 2003.