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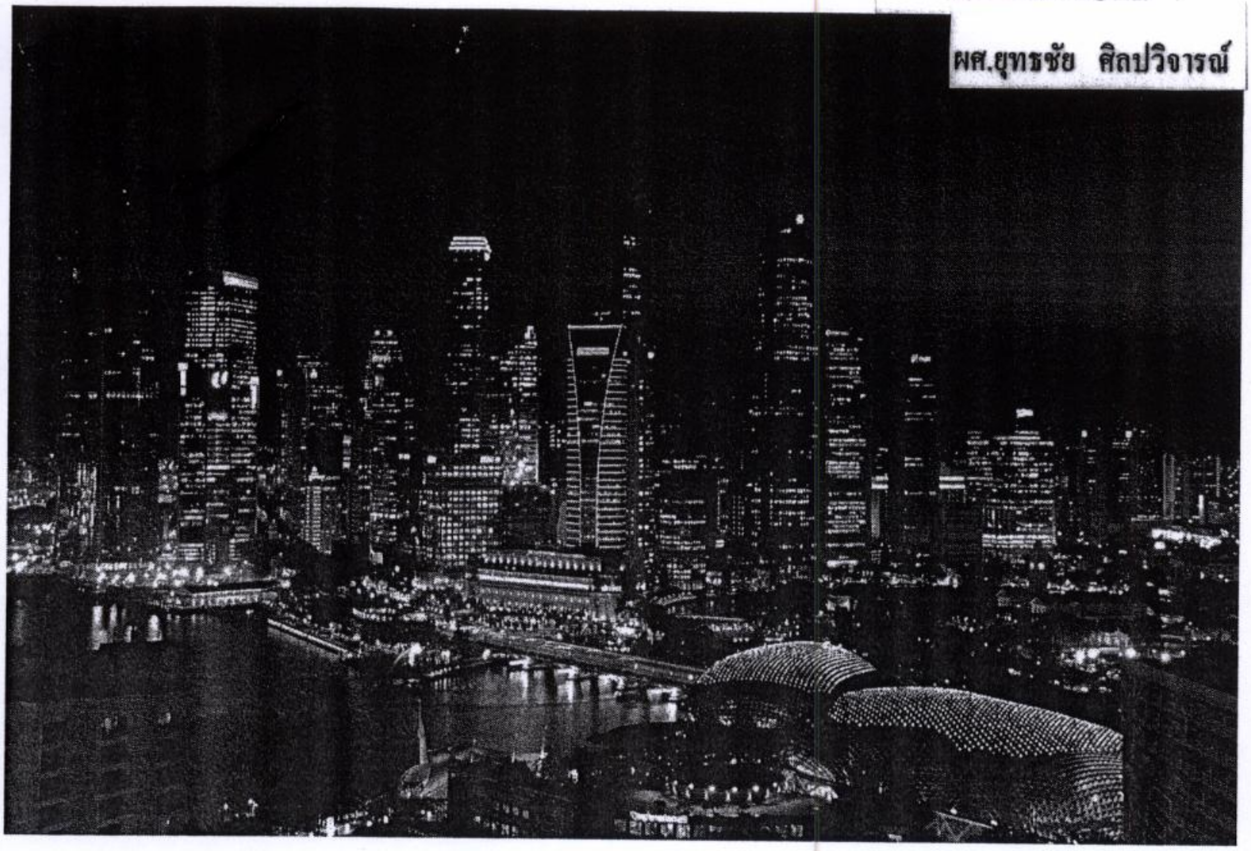

The 9th IEEE International Conference on Power Electronics and Drive Systems

IEEE PEDS 2011

The Amara Hotel, Singapore
5 – 8 December 2011

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The 9th IEEE International Conference on Power Electronics and Drive Systems
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Veerachary Mummadi
India

[3]Institute of Energy Technology, Aalborg University, Denmark
[4]Department of Electrical Engineering, National Sun Yat-sen University, Taiwan

In this paper, a microgrid hierarchical control scheme is proposed which includes primary and secondary control levels. The primary level comprises distributed generators (DGs) local controllers. The local controller mainly consists of active and reactive power controllers, voltage and current controllers, and virtual impedance loop. A novel virtual impedance structure is proposed to achieve proper sharing of non-fundamental power among the microgrid DGs. The secondary level is designed to manage compensation of voltage harmonics at the microgrid load bus (LB) to which the sensitive loads may be connected. Also, restoration of LB voltage amplitude and microgrid frequency to the rated values is directed by the secondary level. These functions are achieved by sending proper control signals to the local controllers. The simulation results show the effectiveness of the proposed control scheme.

130 Comparative Evaluation of Harmonic Compensation Capability of Active Power Filter with Conventional and Bacterial Foraging Based Control

S. S. Patnaik and Prof. A. K. Panda
Department of Electrical Engineering, National Institute of Technology, Rourkela, India

Optimizing the performance of power system networks using conventional methods is quite difficult because of the complex nature of systems that are highly non-linear and nonstationary. In this paper, it is proposed to implement Bacterial foraging (BF) optimization to the conventional shunt active power filter (APF). A comparative analysis of the APF performance is carried out for BF based and conventional approach under unbalanced supply voltage. The instantaneous active and reactive current components (i_d-i_q) method of reference compensation current generation; having greater sensitivity to harmonics and unbalances has been utilized here. Extensive MATLAB simulations are carried out and results demonstrate that the APF with proposed implementation of BF algorithm outperforms the conventional APF in terms of both convergence rate and current harmonic compensation.

186 An Improvement of Synchronously Rotating Reference Frame Based Voltage Sag Detection for Voltage Sag Compensation Applications under Distorted Grid Voltages

Y. Sillapawicharn, Y. Kumsuwan
Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200 Thailand

An improvement of synchronously rotating reference frame based voltage sag detection for voltage sag compensation applications under distorted grid voltages is proposed. The voltage sag detection is the one of important parts in the voltage sag compensation processes. In the past, the conventional synchronously rotating reference frame (CSRRF) based voltage sag detection is widely used in the voltage sag compensation applications. Its disadvantage is a long delay of detection time. This means the next process initiation of voltage sag compensation is also delayed, and then the load voltage can be affected from voltage sag. The modified synchronously rotating reference frame (MSRRF) based voltage sag detection is able to detect the voltage sag in a short delay of detection time by differentiator employment. However, its operation under the distorted grid voltages condition is unavailable because of the sensitivity of differentiator action to the high frequency components that caused by voltage harmonic. This paper proposed the improvement of MSRRF based voltage sag detection under distorted grid voltages. The operation of proposed improved MSRRF, MSRRF, and CSRRF based voltage sag detections are investigated via computer simulation to verify the advantage of proposed voltage sag detection.

Session Applications of Power Electronics in Power System and Generation/FACTS I (APEPSG-I)
Date/Time Tuesday, 06 December 2011/14:00 – 15:40 hrs
Venue Connection Room 4
Chair Prafulla Chandra Panda, National Institute of Technology, Rourkela, Orissa, India

Welcome Message from Conference Chairman

With the exponential growth of energy usage, rapid depletion of fossil-fuel and rising cost of non-renewable energy resources, the energy security and access, the environmental impacts of energy usage and at the same time with distributed and clean energy generation becoming widespread and important. Power Electronics is the enabling technology that deals with the conversion and control of electrical energy and supports a wide range of application energy related areas such as transportation, power supplies, renewable energy, energy harvesting, energy scavenging, lighting, displays, photovoltaics, wind turbines, fuel cell, and energy saving systems etc.

In view of the growing importance of power electronic technology, the international biennial conference on Power Electronics and Drive Systems was originated in Singapore in 1995. Since then the PEDS Conference series has been running successfully on a biennial basis in the Asia and Pacific region. I am happy that it has come back to Singapore almost after an interval of 8 years (the last one held in Singapore was in 2003) and will be the 9th PEDS Conference. It tries to bring together professionals and executives in the power electronics and electric drives and energy sector, electrical power companies, manufacturing industries, research institutes and educational bodies to share and exchange ideas and information pertaining to power electronics and electric drive technologies.

In the 3-day technical sessions, we will have 216 paper presentations coming from 38 countries. Besides technical paper presentations, there will also be one full-day for tutorials with four different topics, a plenary keynote session and an exhibition.

Singapore is only one of two cities in the world to have a significant area of primary rainforest (at the Bukit Timah Hill) within its boundaries. The walk in the rain forest can be a relaxing experience. Or, another good choice will be to visit the National Orchid Garden, which is perhaps the best orchid garden in Singapore. With its friendly and welcoming people, state-of-the-art infrastructure and something new happening almost every day, Singapore will definitely provide an enjoyable experience during your stay.

We hope you enjoy the visit to Singapore and have a pleasant conference.

Sanjib K. Panda
Conference Chairman

Message from Technical Programme Chairman

Power Electronics as a cutting edge technology has come a long way since the first PEDS conference in 1995. Although it may be now regarded as a mature technology, there are still many areas where improvements and innovations are frequently produced. These are in many ways due to the up-tick in applications such as renewable energy systems, smart grids, electro-mobility and green buildings. Hence it is important for power electronics conferences such as the PEDS to continue to provide regular forums for industrial and academic researchers to report their latest contributions to knowledge capital in power electronics and drives systems, and to network with each other.

PEDS has returned to its venue of origin of Singapore in 2011, and I am pleased to serve as its Technical Program Chair again. We look forward to the presentations of over 200 high quality papers in the 3-day conference. The technical program is made possible through the hard work of the numerous peer reviewers and I would like to take this opportunity to thank all of them. Most of all, I should also thank and congratulate all the authors of these papers, many of them have been loyal and consistent supporters of the PEDS series of conferences. I wish all PEDS-2011 conference delegates an enjoyable experience in this Uniquely Singapore.

King-Jet Tseng
Technical Programme Chairman

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Dian Guo Xu, *China*
Longya Xu, *USA*
Abdul Halim Bin Mohamed Yatim, *Malaysia*
Zhengming Zhao, *China*
Georges Zissis, *France*
Udaya Madawala, *New Zealand*
John Y. Hung, *USA*

IEEE PEDS 2011 Conference Programme Schedule

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		Lunch	Lunch	Lunch
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		Tea Break	Tea Break	Tea Break
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APEHIA-I: Applications of Power Electronics in Home Appliance, Industry and Aerospace I
APEHIA-II: Applications of Power Electronics in Home Appliance, Industry and Aerospace II
APEHIA-III: Applications of Power Electronics in Home Appliance, Industry and Aerospace III
APEPSG-I: Applications of Power Electronics in Power System and Generation/FACTS I
APEPSG -II: Applications of Power Electronics in Power System and Generation/FACTS II
DGSG-I: Distributed Generation and Smart-Grid I
DGSG-II: Distributed Generation and Smart-Grid II
HSSS-I: Hard-Switching and Soft-Switching Static Power Converters I
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MDMC-II: Motion Drives and Motion Control II
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MSPE-I: Modelling & Simulation in Power Electronics I
PEET-I: Power Electronic Emerging Technologies I
PIC-I: Power Integrated Circuits I
PQHS-I: Power Quality Issues, Harmonic Problems and Solutions I
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PS-I: Poster Session I
PS-II: Poster Session II
PSPC-I: Power Semiconductors, Passive Components and Packaging Technologies I
RET-I: Renewable Energy Technologies I
RET-II: Renewable Energy Technologies II
RET-III: Renewable Energy Technologies III
RET-IV: Renewable Energy Technologies IV
SMPS-I: Switch-Mode Power Supplies and UPS I
SMPS-II: Switch-Mode Power Supplies and UPS II

IEEE-PEDS 2011 Extended Digest Accepted

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13	Adaptive Sliding Mode Speed Control for Wind Turbine Systems *Adel Merabet, Jogendra Thongam, Ibrahim Hussein*	Adel Merabet	Oral	Canada
15	A Fast and Efficient Scheme for Maximum Peak Power Tracking of a PV Cell Under Partial Shading Conditions *Sree Harsha Angara, Nikhil Naik, Vimal Bhanot*	Sree Harsha Angara	Oral	India
19	A Novel Voltage Equalizer for Electric Double Layer Capacitor *Keiju Matsui, Keiju Matsui, Takumi Nakashima, Masaru Hasegawa*	Keiju Matsui	Poster	Japan
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25	A Method of Tracking Maximum Power Points in Variable Speed Wind Energy Conversion Systems *Jogendra Thongam, Pierre Bouchard, Mohand Ouhrouche, Adel Merabet*	Jogendra Thongam	Oral	Canada
26	Gradient Approximation Based Maximum Power Point Tracking for PV GridConnected System *Ahmed Abo khalil*	Ahmed Abo khalil	Oral	Egypt
28	A New Wind Turbine Simulator With Squirrel Cage Induction Motor for DFIG Wind Power Generation Systems *Ahmed Abo khalil*	Ahmed Abo khalil	Poster	Egypt
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An Improvement of Synchronously Rotating Reference Frame Based Voltage Sag Detection for Voltage Sag Compensation Applications under Distorted Grid Voltages

Y. Sillapawicharn, Y. Kumsuwan
Department of Electrical Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200 Thailand

***Abstract*-An improvement of synchronously rotating reference frame based voltage sag detection for voltage sag compensation applications under distorted grid voltages is proposed. The voltage sag detection is the one of important parts in the voltage sag compensation processes. In the past, the conventional synchronously rotating reference frame (CSRRF) based voltage sag detection is widely used in the voltage sag compensation applications. Its disadvantage is a long delay of detection time. This means the next process initiation of voltage sag compensation is also delayed, and then the load voltage can be affected from voltage sag. The modified synchronously rotating reference frame (MSRRF) based voltage sag detection is able to detect the voltage sag in a short delay of detection time by differentiator employment. However, its operation under the distorted grid voltages condition is unavailable because of the sensitivity of differentiator action to the high frequency components that caused by voltage harmonic. This paper proposed the improvement of MSRRF based voltage sag detection under distorted grid voltages. The operation of proposed improved MSRRF, MSRRF, and CSRRF based voltage sag detections are investigated via computer simulation to verify the advantage of proposed voltage sag detection.**

I. Introduction

In recent years, the voltage sag is one of the major factors that affects the quality of power supply which occurs in a power system. Voltage sag is short duration decrements (between 0.1pu-0.9pu) in voltage amplitude from one-half to several seconds. Several studies report that 92% of all disturbances in electrical power distribution systems are due to voltage sags [1]. It has a significant influence on electronic equipments such as computers, programmable logic controllers, variable speed drives, or process control devices.

Voltage sag problem can be compensated by several compensation methods [2]–[4]. Since the voltage sag detection plays an important role of voltage sag compensation system, then the shortest delay time of voltage detection is required. An employment of CSRRF based voltage sag detection causes the longer delay time which caused by low cut-off frequency of low pass filter (LPF) is introduced. The shorter delay time can be gained by using of MSRRF based voltage sag detection [5]. In practice, the grid voltages may contain harmonics and be distorted then the operation of MSRRF based voltage sag detection can be affected by these distorted grid voltages and failed detection may occur. However, the issue of distorted grid voltage sag detection was not discussed in [5]. This paper proposed an improvement of MSRRF based voltage sag detection for voltage sag compensation applications that can be operated under distorted grid voltages with a short delay of detection time when comparing to conventional methods.

II. Synchronously Rotating Reference Frame Based Voltage Sag Detection Control Strategies

A. Conventional Synchronously Rotating Reference Frame (CSRRF) Based Voltage Sag Detection.

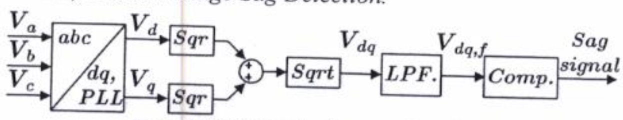

Fig. 1. CSRRF based voltage sag detection.

The CSRRF based voltage detection is shown in Fig. 1. This voltage sag detection method utilizes the *abc-dq* transformation that gives dc quantities (V_d, V_q) proportion to ac quantities of the grid voltages (V_a, V_b, V_c) can be expressed as

$$\begin{pmatrix} V_d \\ V_q \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{pmatrix}\begin{pmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{pmatrix}\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix}. \quad (1)$$

From Fig. 1, $V_{dq} = \sqrt{(V_d^2 + V_q^2)}$, this voltage varies with the grid voltages then the voltage sags can be detected from value of V_{dq}. This V_{dq} is filtered by low-pass filter (LPF) for 2ω or 100-Hz component elimination (for 50-Hz distribution systems). The filtered V_{dq} or $V_{dq,f}$ is finally compared to a dc reference in comparator (i.e. 0.9 pu). The comparator output is a sag signal, which initiates a voltage sag compensation process when the voltage sag occurs.

B. Modified Synchronously Rotating Reference Frame (MSRRF) Based Voltage Sag Detection.

In Fig. 2, the MSRRF based voltage detection is shown. This voltage sag detection method also utilizes the *abc-dq*

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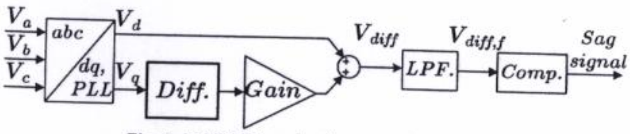

Fig. 2. MSRRF based voltage sag detection.

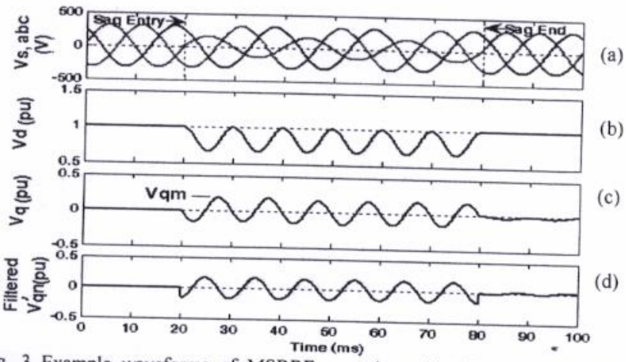

Fig. 3 Example waveforms of MSRRF operation with 0.5pu single-phase voltage sag (a) Grid phase voltages, (b) V_d value, (c) V_q value, and (d) Filtered V'_{qn} value.

transformation, which the differentiator is an additional part. The operation of MSRRF based voltage sag detection is based on 2ω component cancellation as shown in Fig. 3.

In Fig. 3, the example waveforms of V_d and V_q in the case of 0.5pu single-phase voltage sag are illustrated. It can be seen that both of V_d and V_q contain the same amplitude of 2ω components but in different phase. The differential result of V_q (when using phase of V_d as reference) is V'_q which is following

$$V'_q = -2\omega V_{qm}\sin(2\omega t). \qquad (2)$$

And constant value of $1/2\omega$ is used to obtain the V'_q normalization value, V'_{qn}

$$V'_{qn} = V'_q / 2\omega. \qquad (3)$$

It can be noticed that the differentiator is actually used for ıase shifting of V_q, then both of V'_{qn} and V_d have the same amplitude and 180° out-of-phase of 2ω components. Finally, these 2ω components are eliminated by summing of V_d and V'_{qn}, then V_{diff} is obtained as follows

$$V_{diff} = V_d + V'_{qn}. \qquad (4)$$

The V_{diff} signal is filtered by LPF with high cut-off frequency and then it is compared with a dc reference (0.9 pu) to generate the sag signal. It presents that this has no the delay of detection time due to no using of low cut-off frequency of LPF.

C. Improvement of MSRRF Based Voltage Sag Detection.

Although the MSRRF based voltage sag detection provides the short delay of detection time, in the case of operation under distorted grid voltages, the differentiator is influenced by harmonic components due to the action of differentiator is more sensitive with high frequency components.

In MSRRF based voltage sag detection, the main function of LPF is filtering the component of differential result. This differential resultant component (V'_{qn} in (4)) contains only a high frequency component, then the high cut-off frequency of LPF can be used (2 kHz for example). However, in practical case, having the harmonic component from grid voltages, which in practical distribution system, the most existent harmonic components are the fifth harmonic (i.e. 250 Hz) in negative sequence and the seventh harmonic (i.e. 350 Hz) in positive sequence and then they appear as the sixth order harmonic (i.e. 300 Hz) [6] in synchronously rotating reference frame.

Therefore the differential resultant component is highly increased (differential result of high frequency component is larger than differential result of low frequency component) and therefore the sag signal is invalid. To figure out from this problem then the cut-off angular frequency of LPF (ω_c) around a half of the sixth order harmonic is chosen as (5) and then the effect of grid voltages distortion or harmonic can be avoided while the fast detection operation of sag voltage still exists. The cut-off angular frequency ω_c is designed as

$$\omega_c = 6\omega / 2. \qquad (5)$$

For example in the case of 50-Hz distribution systems, the cut-off angular frequency ω_c of LPF is designed at 942.47 radian/second or 150 Hz.

III. Results and Discussion

The model of the voltage sag detection of Fig.1 and 2 are built using Matlab/Simulink simulation software. The simulation model are developed based on voltage sag detections under distorted grid voltages in both of single-phase voltage sag condition and three-phase voltage sag condition. The total harmonic distortion (THD) of the grid voltage under proposed is set to 5% which consists of 4% of fifth harmonic and 3% of seventh harmonic. These conditions are based on harmonic limits standard of IEC standard 61000-3-6 and PRC-PQG-01/1998 (Harmonic regulation in Thailand). It can be seen that the simulation condition is more serious than IEEE standard 519-1992 to ensure the worse case of proposed voltage sag detection operation. The system parameters for simulation of the voltage sag detections are given in Table I.

Table I Parameters of Voltage Sag Detection System

Grid phase voltages, $V_{s,abc}$	220 Vrms, 50 Hz
Grid voltages distortion, THDv	5% THD. (hd5 = 4%, hd7 = 3%)
Voltage sags	Single-phase, 0.5pu. Three-phase, 0.5pu.
Point-on-wave of voltage sags	0 degree
Cut-off frequency of low pass filters, f_c	CSRRF = 50 Hz MSRRF = 2 kHz Improved MSRRF = 150 Hz
Comparator hysteresis band	Lower limit = 0.9 Upper limit = 0.95

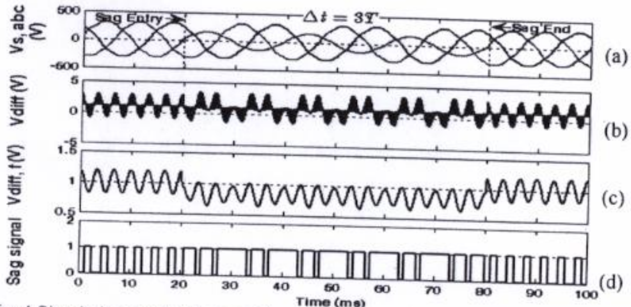

Fig. 4 Simulation results for operation under distorted grid voltages of MSRRF based voltage sag detection with single-phase voltage sag (a) Grid phase voltages ($V_{s,abc}$), (b) Differential value (V_{diff}), (c) Filtered differential value ($V_{diff,f}$), and (d) Sag signal.

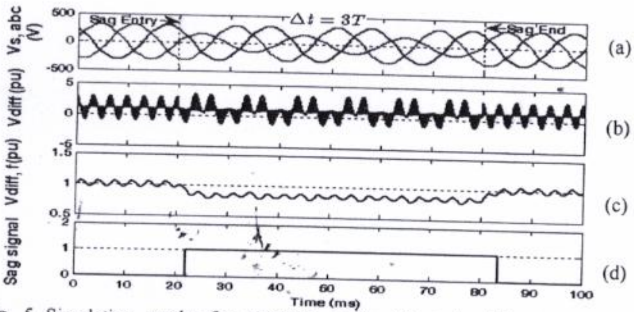

Fig. 5 Simulation results for operation under distorted grid voltages of proposed improved MSRRF based voltage sag with single-phase voltage sag (a) Grid phase voltages ($V_{s,abc}$), (b) Differential value (V_{diff}), (c) Filtered differential value ($V_{diff,f}$), and (d) Sag signal.

Fig. 4 and 5 show the simulated waveforms of the grid voltage ($V_{s,abc}$), differential voltage (V_{diff}), filtered differential voltage ($V_{diff,f}$), and sag signal for 0.5pu single-phase voltage sag detection with 5% THD of the grid voltage when sag duration is $\Delta t = 3T$, respectively. It can be seen that the waveform of V_{diff} and $V_{diff,f}$ in Fig. 4 (b) and (c) contain large 300-Hz component and high frequency component due to differentiator action. This 300-Hz component is caused by armonic and amplified by differentiator action. In Fig. 4 (d), the failed sag signal is taken place because of high cut-off frequency of LPF in MSRRF based voltage sag detection, which is unacceptable.

The simulation results for proposed improved MSRRF based voltage sag detection are shown in Fig.5. Having the suitable cut-off frequency of LPF, then the high frequency component from differentiator action and 300-Hz component in Fig. 5(b) are mitigated as illustrated in Fig. 5 (c). The valid sag signal is finally obtained as seen in Fig.5 (d). It can be noticed that the 300-Hz component is heavily attenuated with a short delay time which introduced by this 150-Hz cut-off frequency LPF.

Fig. 6 depicts the simulated waveforms of the grid voltage ($V_{s,abc}$), V_{dq}, $V_{dq,f}$, and sag signal with the same conditions of Fig. 4 and 5. This voltage sag detection method is impacted from 100-Hz component of *abc-dq* transformation outputs as Fig. 6 (b), then the low cut-off frequency (50Hz)

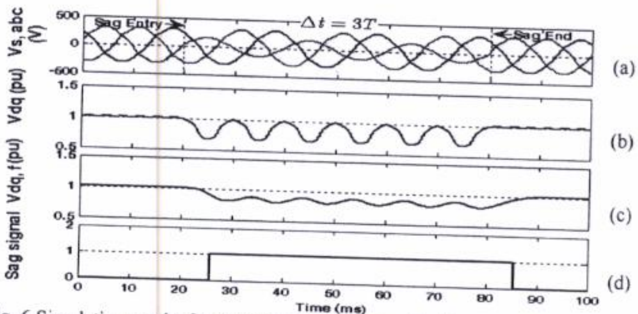

Fig. 6 Simulation results for operation under distorted grid voltages of CSRRF based voltage sag detection with single-phase voltage sag. (a) Grid phase voltages ($V_{s,abc}$), (b) V_{dq} value, (c) Filtered V_{dq} value ($V_{dq,f}$), and (d) Sag signal.

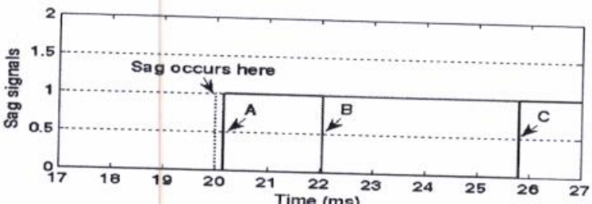

Fig. 7 Voltage sag detection time comparison for single-phase voltage sag, A: MSRRF based with ideal grid voltages, B: proposed improved MSRRF based with distorted grid voltages, and C: CSRRF based with distorted grid voltages.

LPF is used and the result is shown in Fig. 6 (c). It can be distinctly noticed in Fig. 6 (d) that the longer delay time is occurred.

The detection time of MSRRF based voltage sag detection under ideal grid voltages is 170 μs, while the detection time under distorted grid voltages of proposed improved MSRRF based voltage sag detection, and CSRRF based voltage sag detection are 2.01 ms and 5.81 ms respectively as illustrated in Fig. 7. It can be seen that this is a distinct improvement of voltage sag detection that be able to operate in distorted grid voltages and a short delay of detection time is accomplished.

Fig. 8 and 9 show the simulated waveforms of the grid voltage ($V_{s,abc}$), differential voltage V_{diff}, filtered differential voltage $V_{diff,f}$, and sag signal for 0.5pu three-phase voltage sag detection with 5% THD of the grid voltage when sag duration is $\Delta t = 3T$, respectively.

In Fig. 8 (b) and (c), it can be seen that the waveform of V_{diff} and $V_{diff,f}$ of MSRRF based voltage sag detection contain large 300-Hz component and high frequency component due to differentiator action. Even the sag signal is valid in the existing of voltage sag, it is invalid in stage of normal grid voltages as seen in Fig. 8 (d).

The simulation results for proposed improved MSRRF based voltage sag detection are shown in Fig.9. It can be seen that 300-Hz component in Fig. 9 (b) is attenuated as shown in Fig. 9 (c). The true sag signal is finally achieved with a brief delay time as seen in Fig. 9 (d).

Fig. 10 illustrates the simulated waveforms of the grid voltage ($V_{s,abc}$), V_{dq}, $V_{dq,f}$, and sag signal with the same conditions of Fig. 8 and 9. In the case of three-phase voltage

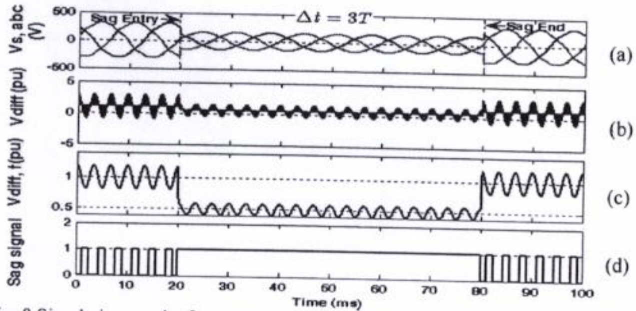

Fig. 8 Simulation results for operation under distorted grid voltages of MSRRF based voltage sag detection with three-phase voltage sag. (a) Grid phase voltages ($V_{s,abc}$), (b) Differential value (V_{diff}), (c) Filtered differential value ($V_{diff,f}$), and (d) Sag signal.

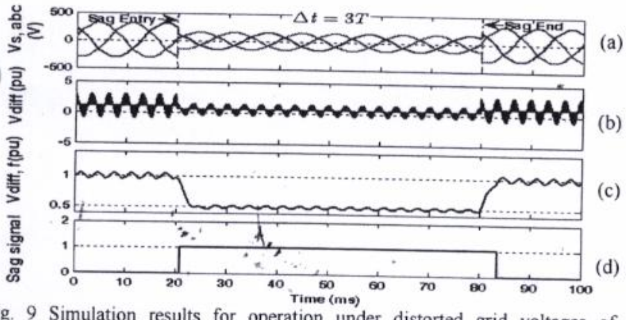

Fig. 9 Simulation results for operation under distorted grid voltages of proposed improved MSRRF based voltage sag detection with three-phase voltage sag. (a) Grid phase voltages ($V_{s,abc}$), (b) Differential value (V_{diff}), (c) Filtered differential value ($V_{diff,f}$), and (d) Sag signal.

sag, the abc-dq transformation outputs are free from 100-Hz component as shown in Fig. 10 (b). However, using of low cut-off frequency LPF, the delay of detection time still exists as seen in Fig. 10 (c) and (d).

The comparison of detection times in this case is depicted in Fig. 11. The detection time of MSRRF based voltage sag detection under ideal grid voltages is 65 μs, while the detection time under distorted grid voltages of proposed improved MSRRF based voltage sag detection and CSRRF based voltage sag detection are 0.9 ms and 2.45 ms respectively. It can be noticed that this is an obvious improvement of voltage sag detection that is able to operate in distorted grid voltages and a small delay of detection time is fulfilled.

IV. Conclusion

An improvement of synchronously rotating reference frame based voltage sag detection for voltage sag compensation applications under distorted grid voltages is proposed in this paper. While CSRRF based voltage sag detection is widely used in voltage sag compensation, the long delay of detection time is introduced. The MSRRF based voltage sag detection is able to work with short delay of detection time but it can not be used in distorted grid voltages due to the action of differentiator with high frequency voltage components. The investigation of proposed improved MSRRF based voltage sag

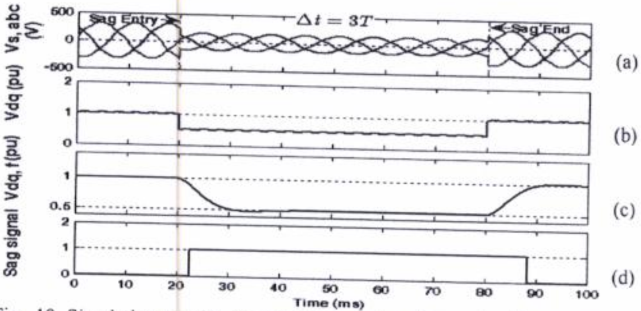

Fig. 10 Simulation results for operation under distorted grid voltages of CSRRF based voltage sag detection with three-phase voltage sag. (a) Grid phase voltages ($V_{s,abc}$), (b) V_{dq} value, (c) Filtered V_{dq} value ($V_{dq,f}$), and (d) Sag signal.

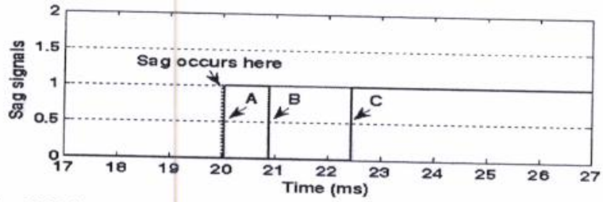

Fig. 11 Voltage sag detection time comparison for three-phase voltage sag, A: MSRRF based with ideal grid voltages, B: proposed improved MSRRF based with distorted grid voltages, and C: CSRRF based with distorted grid voltages.

detection is taken place by reconsideration of its operation under distorted grid voltages. The operation of this proposed improved MSRRF based voltage sag detection is verified by simulation in condition of 0.5pu sag, 5% THDv with both single-phase voltage sag and three-phase voltage sag. As seen on the simulation results, this proposed improved MSRRF based voltage sag detection can detect the voltage sag in very short delay time when comparing to CSRRF based voltage sag detection.

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An improvement of synchronously rotating reference frame based voltage sag detection for voltage sag compensation applications under distorted grid voltages

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ABSTRACT

An improvement of synchronously rotating reference frame based voltage sag detection for voltage sag compensation applications under distorted grid voltages is proposed. The voltage sag detection is the one of important parts in the voltage sag compensation processes. In the past, the conventional synchronously rotating reference frame (CSRRF) based voltage sag detection is widely used in the voltage sag compensation applications. Its disadvantage is a long delay of detection time. This means the next process initiation of voltage sag compensation is also delayed, and then the load voltage can be affected from voltage sag. The modified synchronously rotating reference frame (MSRRF) based voltage sag detection is able to detect the voltage sag in a short delay of detection time by differentiator employment. However, its operation under the distorted grid voltages condition is unavailable because of the sensitivity of differentiator action to the high frequency components that caused by voltage harmonic. This paper proposed the improvement of MSRRF based voltage sag detection under distorted grid voltages. The operation of proposed improved MSRRF, MSRRF, and CSRRF based voltage sag detections are investigated via computer simulation to verify the advantage of proposed voltage sag detection.

INDEX TERMS

- **IEEE Terms**

  Cutoff frequency , Delay , Harmonic analysis , Phase distortion , Power harmonic filters , Simulation , Voltage fluctuations