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Improved Evaluation Method of Flicker considering Disturbances of Power System

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Abstract

This paper studies a more exact flicker evaluation method by detecting power quality disturbances and excluding the effects of power quality disturbances. Up to the present, power quality disturbances affect flicker evaluation index because power quality problems do not have been considered. However, flick index should represent only flicker without power quality disturbances. Thus, in this paper, we present the improved flicker evaluation method which removing the effects of power quality disturbances such as voltage sag and transient caused by fault and inverter/breaker switching. We detect voltage sag and transient using wavelet transform and remove the effects of power quality disturbances from flicker index.

Key Words : Flicker, Power Quality, Distribution, Fft, Wavelet, Disturbances

1. Introduction

The study on the power quality problems such as voltage sag, harmonics, and flicker has become an important subject in recent years. Fluctuating loads such as electric arc furnaces and arc welders may cause voltage fluctuation in a weak power system and affect the illumination in nearby distribution areas[1]. Moreover, a flicker phenomenon at devices like a light irritates human's eyes and the flicker problem has an adverse effect on rolling device and rotating device.

Many reports indicate that a small voltage flicker from 0.3[%] to 0.5[%] in the frequency range of 10[Hz] will cause visible incandescent lamp flickering[2-3] and make people feel uncomfortable.

There are some definitions and standards to quantify the voltage magnitude variation levels, such as IEEE 519-1992 and IEC 61000[4-5]. Many techniques have been studies and a lot of equipment have been developed and applied for measurement of flickers[6-8]. The severity of voltage flicker can be expressed to a short-term severity (Pst) and long-term severity (Plt) and which are recommended by IEC 61000-3-3 and IEC 61000-3-5. However, the voltage flicker of 10[Hz] equivalent value, $\Delta V10$, has been used by some Asian utilities to evaluate the very short flickers. This method converts all amplitude

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modulation components (flicker components) of the waveform into the 10[Hz] equivalent value to represent the equivalent effect[1]. We use △V10 to evaluate the power quality disturbances such as voltage sag and transient.

Voltage sag and transient caused by the fault of the different feeders can increase the flicker index. Furthermore, these power quality phenomena are occurred frequently in power system. Thus the flicker index can be expressed highly. Thus, in this paper, we proposed the improved method that detect the power quality disturbances and remove the effects of these disturbances when the flicker index is evaluated.

2. Voltage Flicker

For a short duration, a voltage flicker waveform can be described as following

$$V(t) = s(t)\sin(2\pi f_{sys}t)$$
$$= \sqrt{2}V_{rms}\left[1+\frac{1}{2}\sum_{n}\Delta V_{\_n}\sin(2\pi f_n t+\varphi_n)\right]\times\sin(2\pi f_{sys}t) \qquad (1)$$

where,

$s(t)$: signal

f_{sys} : system frequency

f_n : flicker frequency

$\Delta V_{\_n}$: flicker modulation

f_n has the range of 0.1-30[Hz]. Fig. 1 shows a simplified voltage flicker waveform, which contains only one modulation component with △V=0.2[p.u.] and f_n =10[Hz].

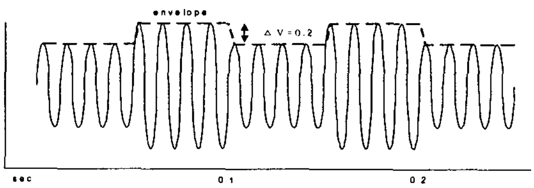

Fig. 1. Voltage flicker waveform with △V=0.2[p.u.] and f_n =10[Hz].

There are many flicker evaluation methods like Pst (10[min]) and Plt (2[hour]).However, In this paper, we use 10[Hz] equivalent value (△V10) because we evaluate short-term flicker (2[seconds]) with and without power quality disturbance.

The voltage flicker of 10[Hz] equivalent value (△V10) is given by equation (2)

$$\Delta V10 = \sqrt{\sum_{n}(a_n \Delta V_{\_n})^2} \qquad (2)$$

The flicker sensitivity coefficient (a_n) is a function of flicker frequency (f_n), which is represented in Table 1[9].

Table 1. Flicker sensitivity coefficient

Freq ([Hz])	a_n	Freq ([Hz])	a_n	Freq ([Hz])	a_n
1	0.261	11	0.989	21	0.622
2	0.423	12	0.965	22	0.590
3	0.563	13	0.929	23	0.559
4	0.681	14	0.888	24	0.529
5	0.781	15	0.845	25	0.499
6	0.860	16	0.803	26	0.470
7	0.923	17	0.763	27	0.442
8	0.967	18	0.726	28	0.413
9	0.993	19	0.689	29	0.385
10	1.000	20	0.655	30	0.371

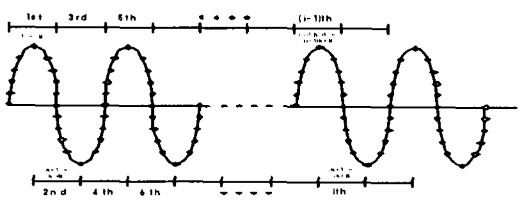

Fig. 2. Moving RMS method

3. Voltage Flicker Evaluation Method

The moving window method is used to calculate the RMS values of the instantaneous voltage V(t) in order to detect power quality event. Fig. 2 represents a moving average method.

Following equation (3) represent the moving window method in Fig. 2.

$$V_{rms}(t) = V_{rms}[i] = \sqrt{\frac{\sum_{m=(i-1)h+1}^{(i-1)h+N} V^2[m]}{N}} \quad (3)$$

where,

h : shifted samples

m : measure sample

We subtract the average value from the RMS value in order to analyze frequency of flicker waveform like equation (5)[1]. Equation (4) represents the average value of the RMS.

$$V_{average} = \left(\sum_{i=1}^{H} V_{rms}[i] \right) / H \quad (4)$$

$$V_s[i] = V_{rms}[i] - V_{average},\ i=1,2,\ldots,H \quad (5)$$

The frequency components of $V_s[i]$ represent the flicker components of V(t). Thus, An FFT is used to calculate the frequency spectrum[17].

$$V[k] = \sum_{i=1}^{N} V_s[i] \exp\left(-j\frac{2\pi ki}{N}\right)$$
$$k = 1,2,\ldots,H/2 \quad (6)$$

Fig. 3 shows the procedure of flicker evaluation method (△V10) and Fig. 4 is the FFT result of 10[Hz] flicker waveform.

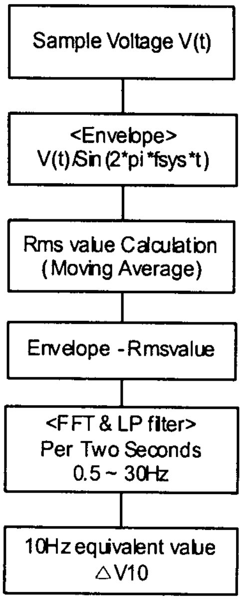

Fig. 3. The procedure of flicker evaluation method (△V10)

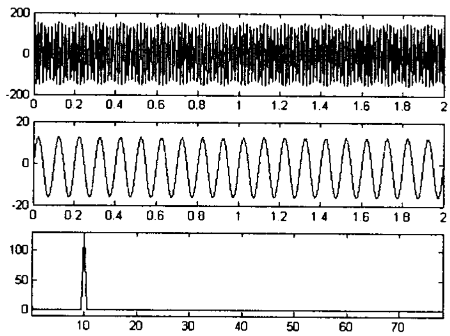

Fig. 4. The FFT result of 10[Hz] flicker waveform(Top10[Hz] waveform, Middle-Envelope curve by subtracting the average value, Bottom FFT result of Middle)

Table 2 represents simple flicker evaluation based on △V10 calculated from the modulation value of flicker amplitude shown in equation (7).

$$\Delta V_{\_n} = \frac{2\sqrt{2}}{V_{average}} V \left[\frac{f_n}{f_s / M} \right] \times 100\%$$

M : total sample data (7)

Table 2. Simple flicker evaluation based on △V10

Flicker Frequency	Flicker modulation[p.u]			
	0.1	0.2	0.3	0.4
10[Hz]	10	20	30	40
20[Hz]	6.56	13.11	19.66	26.22
30[Hz]	3.18	6.35	9.53	12.70

4. Improved Voltage Flicker Evaluation Method

We proposed the more exact evaluation method of flicker by removing the effects of voltage sag and transient. Fig. 5 and 6 represent voltage sag and transient disturbance which can be occurred frequently from power system.

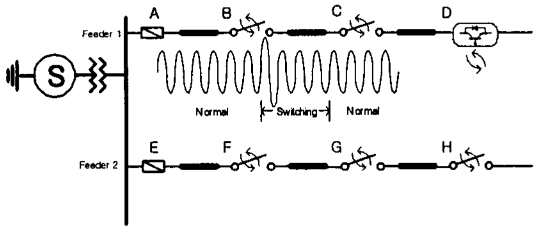

Fig. 5. Transient in power system

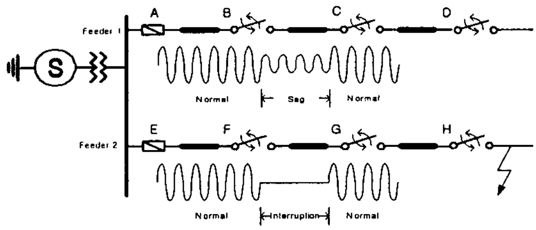

Fig. 6. Voltage sag in power system

Voltage sag and transient are different from flicker. Thus these phenomena should be evaluated using the different index not flicker index. However, we can know that transient and voltage sag affect conventional flicker evaluation method based on FFT as shown in Fig. 7 and 8 and which should be improved.

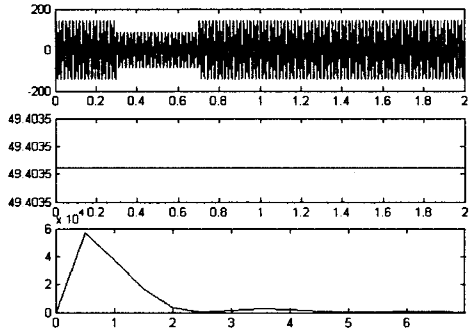

Fig. 7. Flicker evaluation of voltage sag

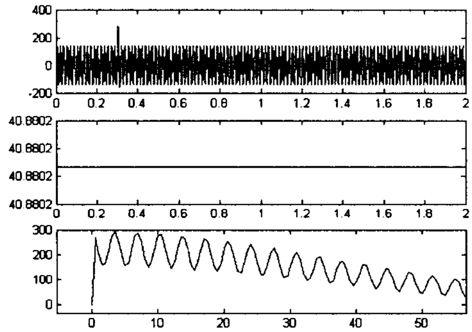

Fig. 8. Flicker evaluation of transient (Top waveform, Middle envelope by subtracting average of rmsvalue, Bottom FFT result)

Wavelet transform can detect voltage sag andtransient and do not detect the flicker as shown in Fig. 9 and 10. Thus the disturbances detected through wavelet should be removed when the flicker is evaluated. Fig. 11 represents proposed algorithm to evaluate the flicker.

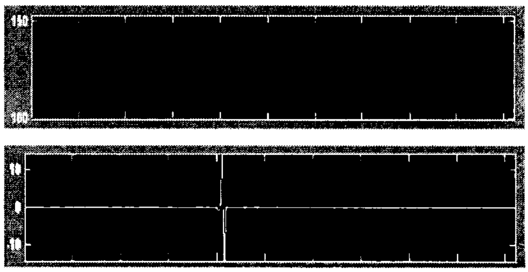

Fig. 9. Wavelet transform result of transient

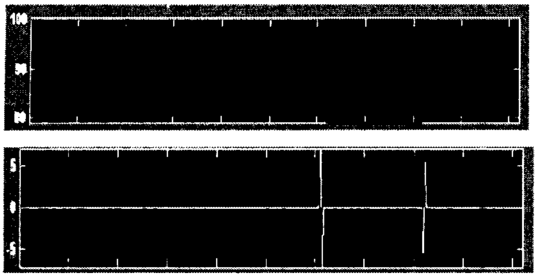

Fig. 10. Wavelet result of voltage sag
(Top waveform, Bottom wavelet result)

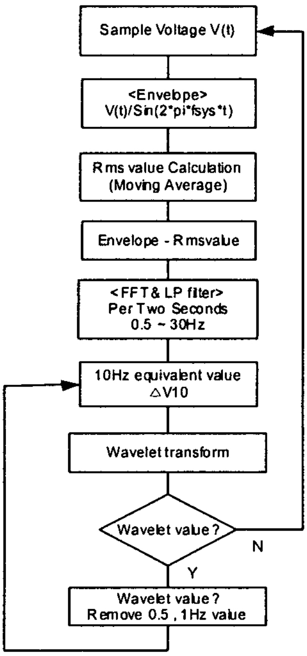

Fig. 11. Proposed algorithm for flicker evaluation

5. Case Studies

Fig. 12 and Table 3 shows a simulation model and the related parameters, respectively.

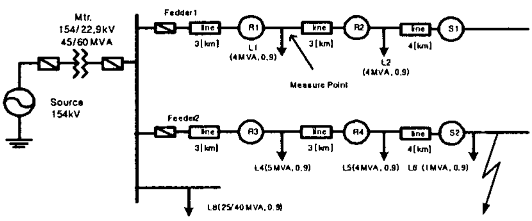

Fig. 12. Simulation model

Table 3. Simulation model parameters

Equivalent Source	Zero sequence imp.[/km]	0.00257+j0.01336 [p.u.]
	Positive, negative Sequence Imp.[/km]	0.00072+j0.00757 [p.u.]
	Supply voltage[kV]	22.9
Distribution Line	Zero sequence imp. [/km]	0.0987+j0.2268[p.u.]
	Positive, negative Sequence Imp.[/km]	0.0386+j0.0698[p.u.]
Mtr.	Impedance	j0.1214[p.u.]
	Rated Capacity	45/60[MVA]
	Transform ratio	154/22.9[kV]

Table 4. Flicker evaluation cases

Without Flicker	
Case1	80[%] sag
Case2	60[%] sag
Case3	40[%] sag
Case4	Interruption
Case5	Two times Sag(80[%])
Case6	150[%] Transient
Case7	200[%] transient
Case8	3rd Harmonic
Case9	5th harmonic
Case10	High Frequency
Case11	Frequency Shift
With Flicker	
Case12	80[%] sag
Case13	60[%] sag
Case14	40[%] sag
Case15	Interruption
Case16	Two times Sag(80[%])
Case17	150[%] Transient
Case18	200[%] transient
Case19	3rd Harmonic
Case20	5th harmonic
Case21	High Frequency
Case22	Frequency Shift

Table 5. Flicker evaluation results
(Compare existing and propose)

Without Flicker		
	Existing	Propose
Case1	5.32	0.01
Case2	10.64	0.01
Case3	15.96	0.01
Case4	26.32	0.01
Case5	5.32	0.01
Case6	34.7	0.03
Case7	69.4	0.03
Case8	0.02	0.02
Case9	0.02	0.02
Case10	0.02	0.02
Case11	0.02	0.02
With Flicker		
Case12	15.32	10.01
Case13	20.64	10.01
Case14	25.96	10.01
Case15	36.32	10.01
Case16	15.32	10.01
Case17	44.7	10.01
Case18	79.4	10.01
Case19	10.02	10.02
Case20	10.02	10.02
Case21	10.02	10.02
Case22	10.02	10.02

The purpose of case study is that comparing existing flicker evaluation algorithm with the proposed flicker evaluation algorithm for many cases.

We make 22 cases as shownin Table 4 Case 1~11 shows a case of power quality disturbances without flicker and Case 12~21 shows with flicker. We assume that flicker frequency is 10[Hz] and modulation is 0.1[p.u.]

Table 5 is the results of flicker evaluation using conventional and proposed methods. This shows that a proposed method is more superior compared with conventional method. The conventional method can evaluate exactly a case with frequency disturbances not voltage disturbances like case 8~11 and 19~22 as well.

6. Conclusions

Flicker and Power quality becomes an important problem as the use of sensitive equipment increases. The power quality disturbances affect flicker index if conventional flicker evaluation method based on FFT is used. Thus, in this paper, we proposed the improved flicker evaluation method. First, flickers are evaluated based on △V10. Second, Voltage sag and transient are detected using wavelet transform. Finally, the effects of power disturbances are removed if disturbances are detected. The proposed method are proved through many case studies

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Biography

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