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Methodological Framework for Industrial Flicker Severity Assessment and Awareness

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Abstract: This study developed a framework of survey design, data collection and an analytical model for the flicker severity level assessment and awareness in Malaysia based on the practical perception of industrial respondents. The identified flicker severity factors (FSF) are considered for different types of equipment for industrial flicker assessment. This study also provides the significant level of awareness, mean of the motivating factors and awareness ranking of various entities upon flicker occurrences. The findings will assist in the formulation of appropriate policies that address the industrial flicker problem in Malaysia as well as indirectly improving the industrial power quality in the country.

Key words: Flicker severity, classification, assessment, perception, flicker severity factors.

INTRODUCTION

Flicker is the most prevalent power quality (PQ) problem in the industry. The percentage of flicker incidents in worldwide are always higher compared other PQ problems and Malaysia is not an exception. The flicker may originate in the power system, but most frequently they are generated by the equipment or load connected to it. For example arc furnaces, welders, alternators, motors, electronic devices, process controllers, frequency converters, current-source inverters and so many industrial equipments (Marcos and Gomez, 2002; Zhang *et al.,* 2005). Prolonged exposure of voltage flicker can gained lethality or shorten the expected life of electronic equipment and machines (Dugan *et al.,* 2004). A study performed by European Copper Institute in 2001 forecasted that the 23.8 % of power disturbances occurs due to the flicker (Chapman, 2001), which is second highest among the types of disturbances that have been considered. Based on damage, defect and short-life of the industrial equipment as well as quality of the final product, the flicker is the most faced problem in Malaysia as shown in Table 1 (Francis, 2009). The number of flicker incidents and percentage of flicker problems are 15 and 57.5 %, respectively in 26 industries. Similarly, in case of voltage sag, the number of incidents are 12 and percentage of voltage sag are 46.2 %, respectively Thus, it is found that the flicker is the most faced problem in the industries.

There have been several studies on the cause of flicker, sources of flicker, evaluation techniques, establishing a flicker index, flicker severity, and generating flicker limit curves that can serve as guidelines to verify whether the amount of flicker is a problem (Bishop *et al*., 1994; Srinivasan, 1991; Grigis *et al*., 1995; Soliman and El-Havary, 2000; Zheng and Makram, 1998; Poisson *et al*., 2000; Galil *et al*., 2002;Marei *et al*., 2004; Hasawi *et al*., 2004). All of these existing methodologies are not well-developed in terms of statistical classification, flicker assessment, its severity analysis and revealing inconsistent performance (Keppler *et al*., 2000; Mazadi and Hosseinian, 2005; Mazadi *et al*., 2007). Thus, industrial flicker severity is an important area that requires assessments, awareness and decisions by the Malaysian high-tech industries, utilities and all power consumers.

Table 1: Industrial power quality problem summaries

Power quality events	Number of incidents and % of PQ problems	
	Number of incidents	Percent
Flicker	15	57.5 %
Voltage sag	12	46.2 %
Voltage swell	11	42.3%
Hoarmonics	6	23.1%
Transient	5	19.2%

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This paper deals with the data obtained from a survey regarding industrial perceptions on flicker for an assessment of flicker severity and awareness. The aim is to increase the awareness level of industry personnel and provide a decision-making tool for industry and utilities consumers. This paper describes a new way to convert a practical and qualitative perception of industrial flicker into quantitative and qualitative assessments, awareness and decisions.

2. Flicker Severity Assessment Methods:

An indusrial flicker severity assessment includes methodological framework, data collection and analytical models. Details of the asessment methods are given below.

2.1. Methodological Framework:

The methodological framework is defined as the detailed statement of the problem, survey framework, data collection and processing, data analysis, severity assessment, and awareness as shown in Fig. 1. The problems of the existing publications have been reviewed to develop a preliminiary assessment (Poon *et al*., 2001; Shen and Tam, 2002; Rawshan *et al*., 2007). A survey framework was developed by creating a questionnaire and a sampling procedure. Some initial questionnaire is pretested for final questionnaire development. The most important part of this framework is data collection and processing, including data recording, entry, coding and computations in order to obtain a flicker severity analysis in the industry. Several flicker severity parameter and indices, such as ASS, SIV and RSIV were developed for flicker severity assessment and awareness.

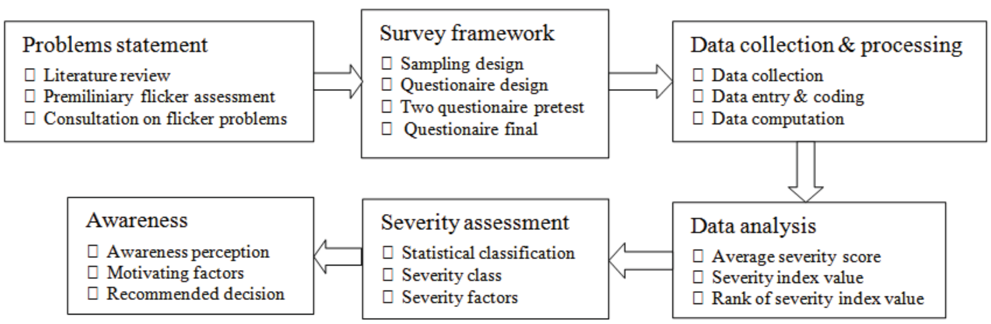

Fig. 1: Block diagram of methodological framework used for industrial flicker severity assessment

2.2. Data Collection:

Data were collected through interviews with technical personnel registered with the high-tech industry between July 2008 and March 2009 in the Klang Valley, Malaysia. In total, 26 industries participated in the data collection, including process industries, light industries, heavy industries, and steel mills. Process industries are mainly composed of semiconductor, air-conditioning, chemical, and pharmaceutical industries. Light industries include manufacturers of plastics, clothes, glass, shoes, and household electronics, where as heavy industries include construction, oil and gas companies. The remaining industry classification includes steel mills. In this study, a stratified random sampling method is applied to the four major groups of industries. In the first stage of the data collection, the samples of the types of industries in high-tech activities were selected. Then, the samples were stratified into three sub-groups in order to perform data collection, data entry and coding and data computation. The final survey was based on 26 samples of high-tech industries. The interviews were based on a set of questionnaires that were pre-tested and modified before use in the survey.

2.3. Analytical Model:

Upon data collection, the data were analyzed by converting qualitative industrial data into a quantitative and statistical value using the SPSS (Statistical Package for the Social Sciences) software. Three models of the flicker severity and indices are as follows.

2.3.1. Average Severity Score (ASS):

The study employed the weighted average model to assess the relative significant level of the flicker severity factor (FSF) for different types of equipment in industry based on how the equipment is affected and damaged. The weighted average model is written as:

$$ASS_i = \frac{\sum_{j=1}^{4} X_j \, N_{ij}}{N} \tag{1}$$

where, ASS_i is the average significant score to the severity factor i, and X_j is the flicker severity level, which is assumed to be in between level 1 to level 4 where 1 indicates not a problem at all, level 2 indicates a light problem, level 3 is a moderate problem and level 4 is a severe problem, respectively. Also, N_{ij} is the number of respondents who give the factor i for the level Xj and N is the total number of respondents.

2.3.2. Severity Index Value (SIV):

To calculate the ASS_i, the four level scales for X need to be converted into numerical scales for the purpose of simplifying the flicker severity index value. To rank the significance among all the severity factors, we employed the combined value of the weighted average and the coefficient of variation. The coefficient of variation measured by the severity index value (SIV) is given below:

$$SIV_i = ASS_i + \frac{ASS_i}{\delta_i} \tag{2}$$

where, SIV_i is the coefficient of variation for the severity i, ASS_i the average significant score of the flicker severity factor i and δ_i is the standard deviation of the significance score for factor i.

2.3.2. Rank of Severity Index Value (RSIV):

After calculating the *SIV*, we ranked the flicker severity factor (FSF) of the severity index value according to the RSIV significance level.

RESULTS AND DISCUSSION

There are many ways to assess industrial data that has been collected in qualitative and quantitative forms. However, we have limited our focus to only the flicker severity assessment and awareness in this paper. This study presents 15 flicker severity factors (FSFs) for an industrial flicker assessment. The identified severity factors are considered as having different effects on the different types of equipment in Malaysian industries. The estimated results of the weighted value of the ASS, standard deviation δ, severity index value (SIV) and the rank of severity index value (RSIV) are summarized in Table 2. The relative significance levels from the 26 respondents for each severity factor shows that the highest ASS is 4.00 for the synchronous motor (FSF-2), electrolyser (FSF-4), static rectifier (FSF-9) and auto-platter (AP), conveyer belt (CB) and moving part (FSF-14). This indicates that FSF-2, FSF-4, FSF-9 and FSF-14 cause the most severe effects or most significant damage. This also means that FSF-8 is the least affected by the flicker and incurs the least amount of damage caused by flickering, i.e., level 1. This study used the combined value of the weighted average and the coefficient of variation to rank the significance of the flicker severity factors. It should be mentioned that the ASS is a weighted average and can be used to rank all of the FSFs. An effective assessment of ranking attributes should consider both the weighted average and the coefficient of variation. The coefficients of variation are measured by the SIV model.

Table 2 also shows the results of the SIV and the RSIV. The results show that the highest SIV is 11.33 for the inverter (FSF-6) and the lowest SIV is 0 for the synchronous motor (FSF-2), electrolyser (FSF-4), arc furnace (FSF-8), static ectifier (FSF-9) and auto-platter (AP), conveyer belt, and moving parts (FSF-14). In fact, the result shows that the ranks of the flicker severity factors did not change much for the two criteria of ASS and SIV. It is reasonable to assume that the ranks established by either ASS or SIV effectively provide a flicker severity assessment for the industrial devices. Thus, flciker severity is perceived through the average score of severity, standard deviation, severity index value and provided the rank of severity index value for implementing the industrial flicker assessment.

This study provides empirical evidence on the significant level of awareness for flicker severity. The findings will assist in the formulation of appropriate policy interventions in addressing the awareness on industrial flicker problem in Malaysia and indirectly improving the power quality of the industry in the country.

Table 3 shows the awareness perception of various entities on flicker occurrences, in which 73.1 % individuals of Tenega National Berhad (TNB) are aware of flicker and 26.9 % of individuals are not aware of flicker. Similarly, other entities also provides flicker awareness is 50 %. However, in company level, government level and academic and researcher level the flicker awareness are 30.8 %, 15.4 % and 11.5 %, respectively. This analysis would hinder the entities to investigate the source and occurrence of flciker severity problem as well as would increased the awareness level of the industrial personnel and entities.

Table 2: Weighted value of ASS and severity index value for different FSF

Flicker Severity Factor (FSF)	Average Score of Severity (ASS)	Standard Deviation (δ)	Severity Index Value (SIV)	Rank of Severity Index Value (RSIV)
FSF-1	3.25	0.71	7.85	6
FSF-2	4.00	0.00	0.00	11
FSF-3	3.33	0.62	8.73	3
FSF-4	4.00	0.00	0.00	11
FSF-5	3.67	0.82	8.16	5
FSF-6	3.71	0.49	11.33	1
FSF-7	3.33	0.82	7.42	8
FSF-8	3.00	0.00	0.00	11
FSF-9	4.00	0.00	0.00	11
FSF-10	3.04	0.88	6.51	10
FSF-11	3.30	0.67	8.19	4
FSF-12	3.27	0.79	7.44	7
FSF-13	3.40	0.89	7.20	9
FSF-14	4.00	0.00	0.00	11
FSF-15	3.50	0.58	9.56	2

The statistic proves the lack of awareness in power quality contributes to the severity of flicker in Malaysia. Thus, in order to provides guidelines on the aspect, the respondent from various company had agreed to share their experience and view on the effectiveness of the factors in motivating the industry to take note and solve the severe flicker issue. The awareness of the public can be increased through the motivating factors such as i) education and awareness ii) legislation and regulation iii) financial incentives iv) guidelines and training support v) invention of appropriate mitigating technology and vi) research and development. The six motivating factors is evaluated using 4 scale such as 1 for most important, 2 for very important, 3 for important and 4 for less important as shown in Table 4. It shows that the financial incentive for solving or reducing flicker problem is considered the most practical by the perception of the industrial personnel. This is followed by the government laws and regulation. The the availability of the appropiate mitigation technology are also important in motivating flicker awareness to the industrial personnel. Meanwhile, education and awareness, guidelines and training and research and development are plays least significant role in increasing the awareness on flicker severity.

Table 3: The awareness perception of various entities on flicker occurrences

Entities	Response	Frequency	Percent	Valid Percent	Cumulative Percent
Malaysian power supply (TNB)	Yes	19	73.1	73.1	73.1
	No	7	26.9	26.9	100.0
	Total	26	100.0	100.0	
Company level	Yes	8	30.8	30.8	30.8
	No	18	69.2	69.2	100.0
	Total	26	100.0	100.0	
Industry level	Yes	13	50.0	50.0	50.0
	No	13	50.0	50.0	100.0
	Total	26	100.0	100.0	
Government level	Yes	4	15.4	15.4	15.4
	No	22	84.6	84.6	100.0
	Total	26	100.0	100.0	
Aacademician and researcher level	Yes	3	11.5	11.5	11.5
	No	23	88.5	88.5	100.0
	Total	26	100.0	100.0	

The result therefore can be greatly used as a guide to consider the steps to be taken in order to counter the damaging effect of flicker in the industries. It also provide guidelines to start being alert and aware from some problems that might be happened due to flicker. The flicker have proven to be the most faced problems in Malaysia industry. Thus, the industry should take precautions in order to avoid loss and damage due to flicker.

Table 4: Mean of the motivating factors and awareness ranking

Motivating factors	Mean	Description	Ranking
Education and awareness	3.54	Less important	4
Laws and regulations	2.96	Very important	2
Financial incentives for solving flicker	2.23	Most important	1
Guidelines and training	4.04	Less important	4
Availability of flicker mitigator	3.04	Important	3
Research and development	4.08	Less important	5

4. Conclusion:

This study assesses the contribution to flicker by analyzing several flicker severity factors. The assessment quantifies the flicker severity by four levels, Level 1 to Level 4 as mentioned earlier. According to the respondents, lightning is the most significant factor that contributes flicker, while the synchronous motor is the least significant in Malaysian industries. The results also indicate that the flicker severity factors FSF-2, FSF-4, FSF-9 and FSF-14 are considered the most severe or cause the most significant damage in the Malaysian industries. This study finds that the severity factors FSF-6, FSF-15, FSF-3, FSF-11, FSF-5 have the highest RSIV rank. On the other hand, FSF-2, FSF-4, FSF-8, FSF-9 and FSF-14 have the lowest RSIV rank, whilst the lowest severity index value by the respondents. Thus, the higher the severity index value, the higher the rank severity index value will be.

This study also provides the awareness perception of various entities that would hinder the entities to investigate the source and occurrence of flicker severity problem. A guideline is recommended through evaluating the motivating factors, which will assist the industry or the government to make an appropriate policy for increasing the awareness on industrial flicker problem in Malaysia. Thus, local authorities in industry or the government should provide guidelines for industry personnel specifying flicker severity factors for the equipment via government industrial ordinance.

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