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Voltage Flicker Noise in Wind Turbine Output

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Abstract : This is paper provides specifics of voltage flicker noise that may be initiated in the output voltage of the horizontal axis upwind wind turbine located at any given site for a given tower height and blade length. Basics of voltage flicker noise, causes, impacts, range and computation of voltage flicker is discussed in this paper.

Keywords : *Voltage flicker; wind shear; wind turbine.*

1. BASICS OF VOLTAGE FLICKER

Bulb light is varied due to voltage flicker. Voltage flicker can be computed in terms of human sensitivity to the alteration in the intensity of the bulb light. The alteration in the light intensity is initiated as a result of voltage variation. Frequency of the voltage alteration is up to 25 Hz. Voltage flicker is produced due to variation in the voltage. A small variation in the voltage can produce large disturbance. If the frequency of repetitive is in the range of 8 to 10 Hz then the voltage variation produce greater infuriation. In voltage flicker cyclic alteration in the RMS voltage occurs. The variation may be arbitrary or cyclic. The deviation in the voltage is in the range of 90 % to 110 % of nominal voltage. Due to voltage flicker there is a variation in the light output of light sources.

Russel B chadwic designed a radar for deflection of wind shear. H designed a radar for airport applications. The design of radar is done in two steps. In the first step he conducted field experiment and from the field experiment he got stastical results. In the second step, the results are used to design a clean air radar for detection of wind shear. [1]

Ronald G Freitag studied a wind shear detection system. He modified a modular avionics radar *i.e.* MODAR. MODAR is a modular avionics radar. It is useful in detection of wind shear for aircraft applications. He provided a block diagram of modular radar to detect wind shear. [2]

Robert F Stengel provided an expert system to avoid wind shear. In strong wind shear there is a severe hazard to aeroplane. The performance of the airplane is hampered. The pilot faces a severe wind shear only once or twice in a life time. The wind shear data is very important for operation of aeroplane. [19]

Walid SE Abdel Latif computed voltage flicker in fixed speed wind turbines. Wind turbines produced voltage variations. He considered induction generators for wind turbines. He used wind speed and turbine models. He also studied the impact of site on voltage variation. He used static synchronous compensator to reduce voltage flicker. For highly inductive impedance of grid static compensation method is effective. [16]

V. P. Suppopni studied voltage flicker of medium wind turbines. He analysed the voltage flicker of wind turbines connected to distribution network. He used simulation for study. He developed model of electrical and mechanical components of wind turbines system. The behavior of meduium wind turbine is explained by him. He used Turbsim and simulink software. He developed wind speed model for wind turbine. according to him blade flexibility is important parameter for study of voltage flicker. [23]

Weihau Hu studied voltage flicker in PMSG wind turbines. Wind turbines are sources of varying power. These wind turbines produce voltage flicker in continuous operation. He considered various parameters like mean speed, 3 p torque oscillations, turbulence intensity, tower shadow effect and wind shear for study of voltage flicker. Output reactive power control can be used to reduce voltage flicker in continuous operation. He developed a simulation model for variable speed wind turbines. He used PSCAD software for study. [26]

2. DEFINITIONS OF VOLTAGE FLICKER

Voltage flicker can be explained in various ways. Tao sun has goven one definition of voltage flicker. According to Tao sun voltage flicker is defined s the sensation of instability in the in the light output. The luminance change with time. The change in the intensity of of light irritates consumers.

Jens Schoene et al. called voltage flicker as an change in the amplitude of the voltage. He treated main signal as a carrier signal and voltage flicker as a varying signal. According to Sankaran voltage flicker is a a alteration in the voltage for a duration in which human eye can observe the change in the intensity of light.

3. COMPUTATION OF VOLTAGE FLICKER

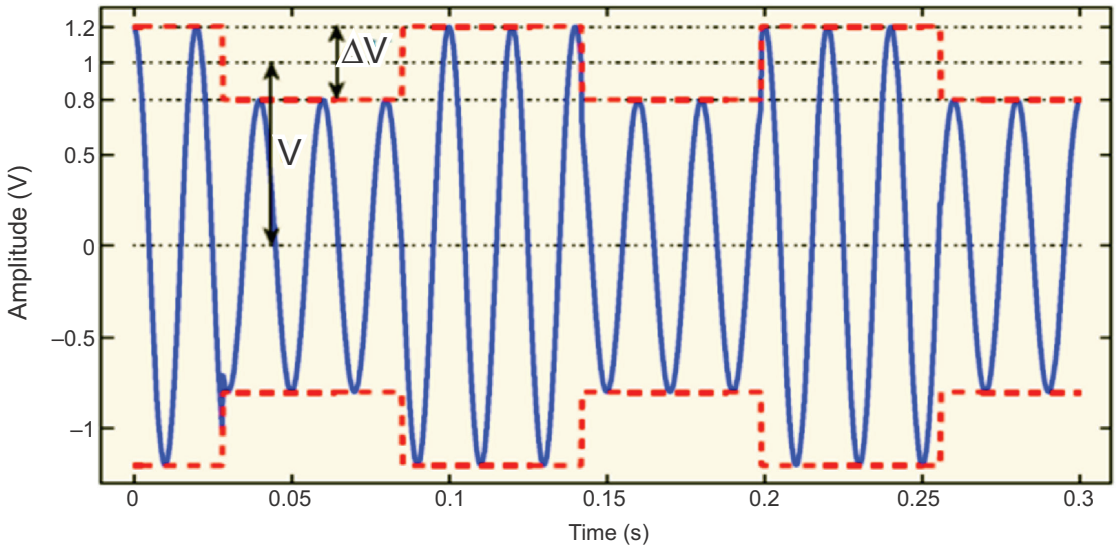

Figure 1: Voltage flicker waveform with rectangular variation

According to sankaran et al. voltage flicker may be treated a s aalteratyion in voltage as compared to nominal voltage. According to him the voltage flicker is expressed in percentage. [19] *e.g.* if the normal voltage is 120 V. If the volage changes to 124 V. then if changes to 116 volt. Then the voltage flicker may be computed as $P_{st} = P_{lt} = 100 \times (124 - 117) / 120 = 5.833$ %. Voltage flicker is dimensionless. It has no dimensions. Voltage

flicker may be computed as ratio of change ion the voltage to the average voltage. (ΔV/V). It is expressed as a percentage. Voltage flicker is computed for a specific period. The value of the voltage flicker for short term is computed for 10 minutes and for long term the value of the voltage flicker is computed for a 120 minutes *i.e.* for two hours.

In Fig. 1 rectangular fluctuation of voltage is shown. The frequency of variation is 8.8 Hz. Main signal has a frequency of 50 Hz. The voltage flicker variation may be non repetitive. It may be repetitive. In repetitive variation the voltage fluctuation is in the form of square or sinusoidal variation.

4. RANGE OF VOLTAGE FLICKER

The voltage flicker in the output of the wind turbine should be restricted to Pst = 0.3 or less than 0.3. the wind turbines which are connected to distribution network the limit for the voltage flicker is Pst = 0.35 or less than 0.35. Due to voltage flicker there is production of light flicker. For producing light flicker the voltage flicker in the range of 0.5 % and flicker frequency 6to 8 Hz is sufficient. The range of magnitude of voltage flicker is 0.1 to 7 % of the nominal voltage. The frequency of the voltage flicker is 25 to 30 Hz.

5. COMPARISON OF VOLTAGE FLICKER WITH OTHER POWER QUALITY PARAMETERS

Table 1
Comparison Voltage Flicker With Other Power Quality Parameters

Parameters	*Voltage flicker*	*Voltage swell*	*Voltage sag*
Short definition	Random or cyclic alterations in the RMS voltage in the range of 90 to 110% of nominal voltage can initiate a phenomenon known as "Voltage flicker" in lighting source equipment.	When the RMS voltage is greater than ehe nominal voltage by 10 to 80% for half cycle to 1 minute, than that phenomenis called as voltage swell.	A „sag „ or a „dip „ is opposite to that of a swell. It is the RMS voltage below the normal voltage by 10 to 90% . the time duration is 0.5 cycle to 1 minute.
Duration	Continuous	0.5 cycle to 1 minute	0.5 cycle to 1 minute.
Voltage range	Variations in the RMS voltage between 90 and 110% of nominal	Voltage exceeds the nominal voltage by 10 to 80%	RMS voltage is below the nominal voltage by 10 to 90%

6. GENERAL SOURCES OF VOLTAGE FLICKER

Voltage flicker is caused due to the electronic components connected to the system. It is also caused due to the electrical devices connected tom the system. Voltage variations are produced due to the alterations in the power especially reactive power of the consumer. Switching of large loads also caus voltage flicker. Electric furnace cause voltage flicker. Voltage flicker is caused due to welding machines, arc furnaces, capacitor banks, electric boilers etc.

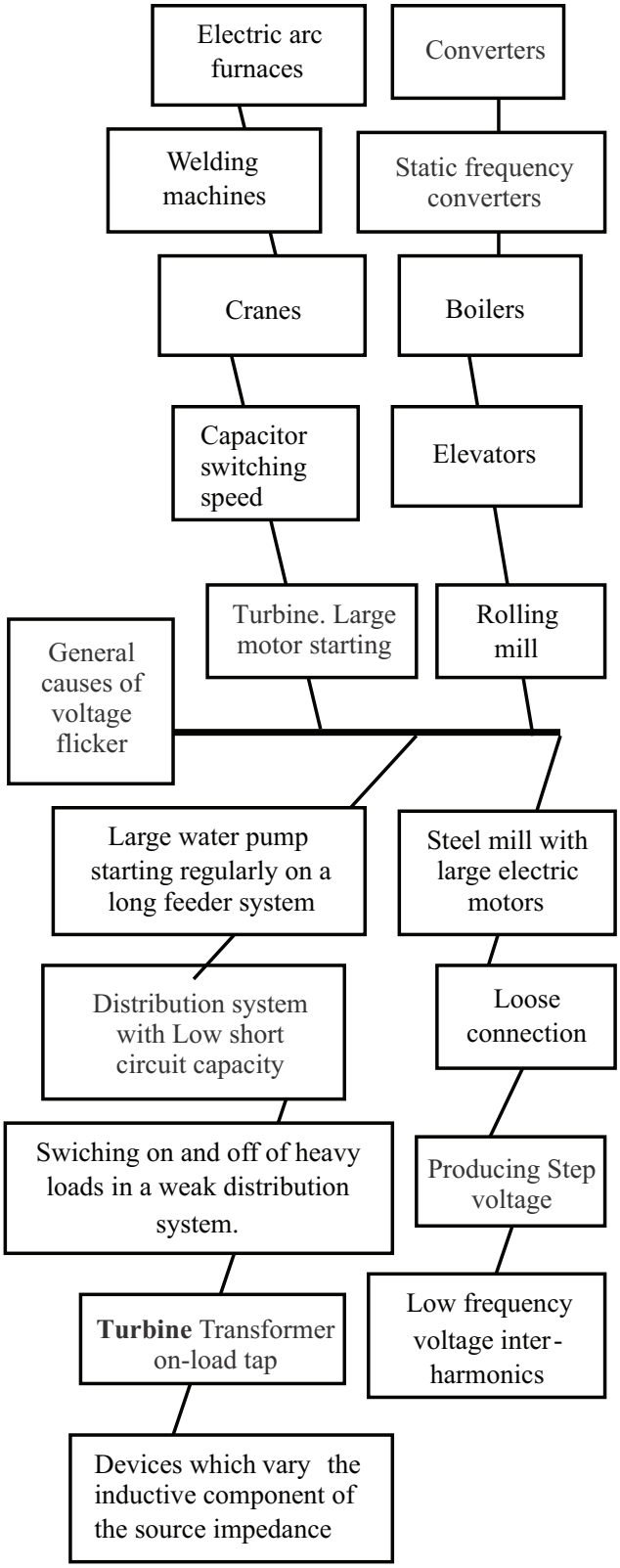

Figure 2: General causes of voltage flicker

7. VOLTAGE FLICKER DUE TO WIND TURBINE GENERATORS

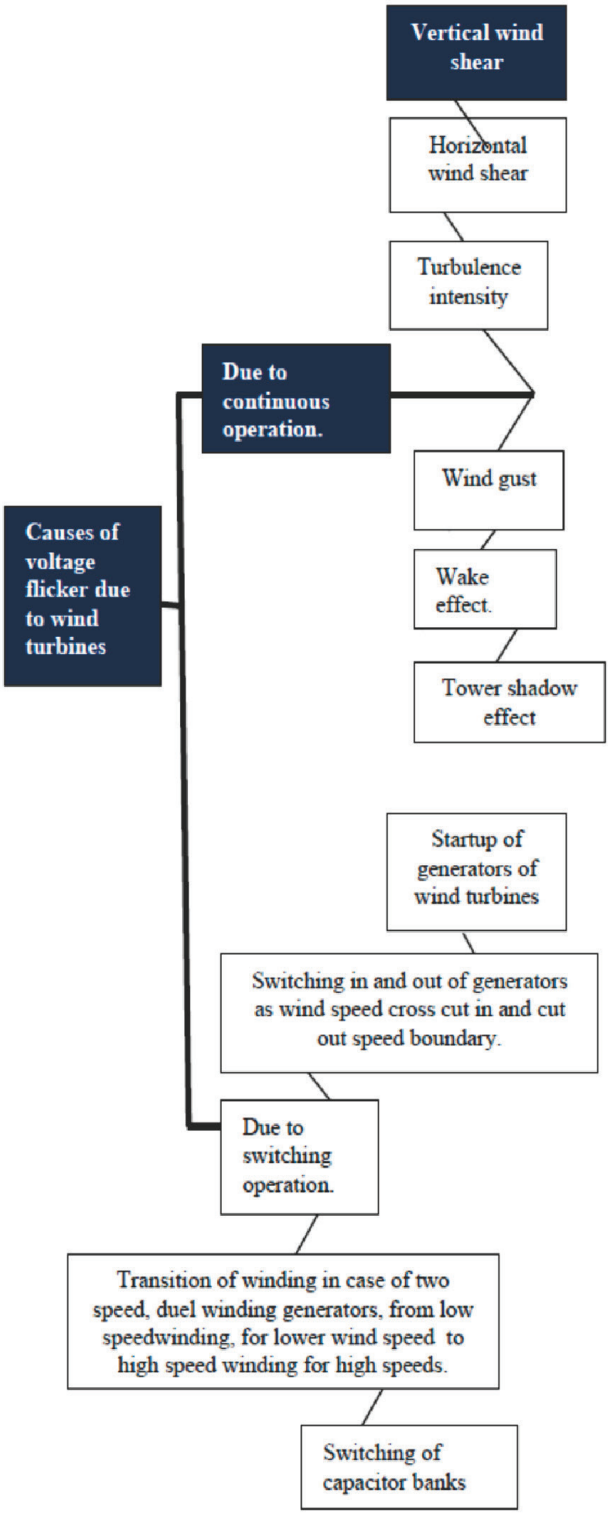

Figure 3: Causes of voltage flicker due to wind turbines

In continuous operation wind turbine produce varying power Due to this voltage e variations are produced at point of common coupling. The voltage flicker is initiated due to turbulence intensity, horizontal wind shear, vertical wind shear, wake effect and tower shadow effect. Due to switching operation also voltage flicker is produced. Wind generators are switched in and switched out when the the wind speed crosses the cut in and cut out speed limit. Besides, transition of winding, in case of two speed, duel winding generators, from low speed winding, for lower wind speed to high speed winding, for high speeds, also initiate voltage flicker.

7.1. Classification Of Voltage Flicker

Figure below gives classification of voltage flicker.

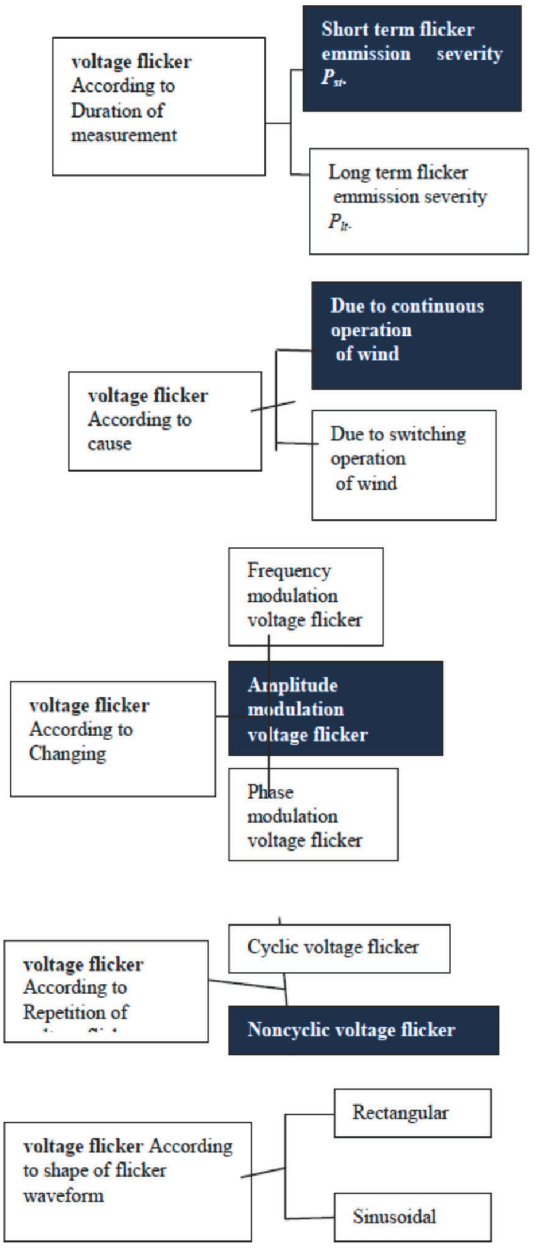

Figure 4: Classification Of Voltage Flicker

8. PARAMETERS AFFECTING VOLTAGE FLICKER

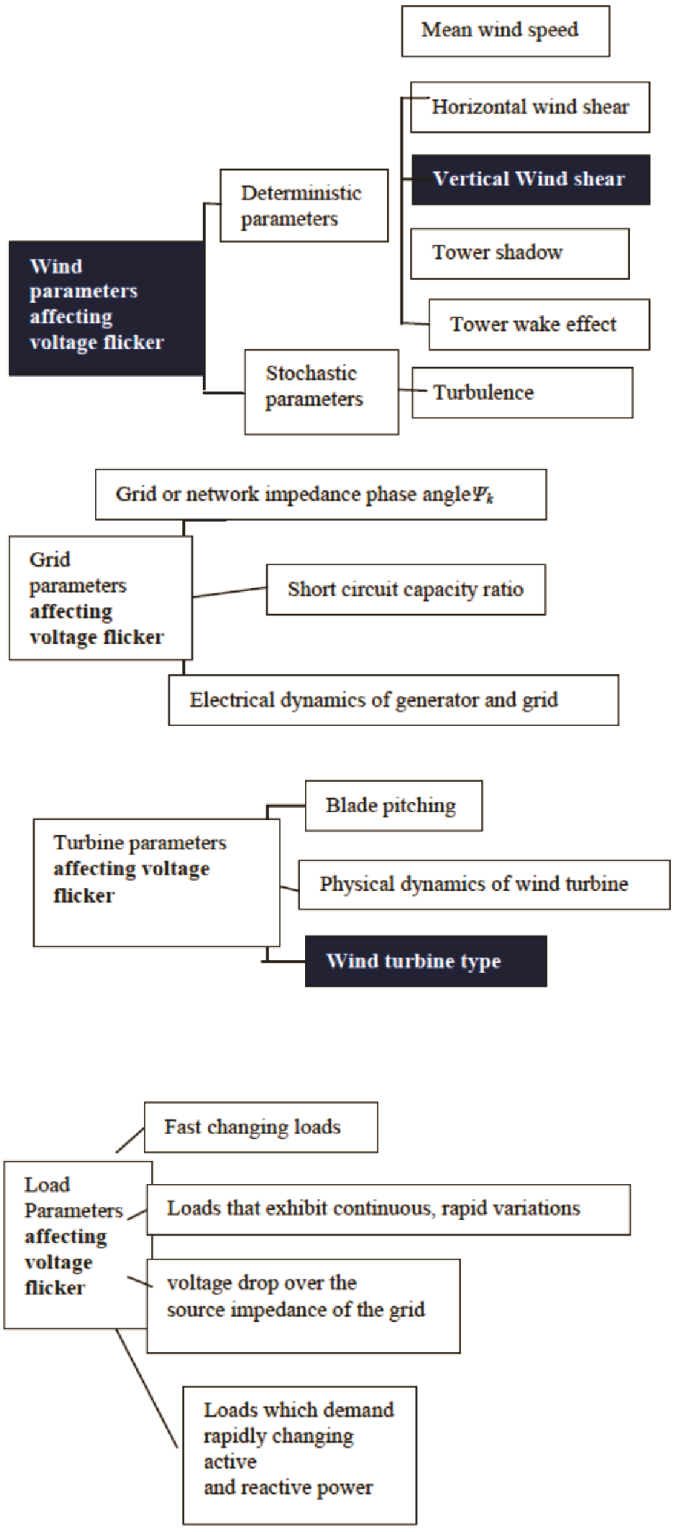

Figure 5: Parameters affecting voltage flicker

9. GENERAL EFFECTS OF VOLTAGE FLICKER

Fig. 5.14 gives bad effects of voltage flicker. Voltage flicker create flicker in incandescent lamp. It affects the production environment. It can malfunction of electrical equipment and devices.

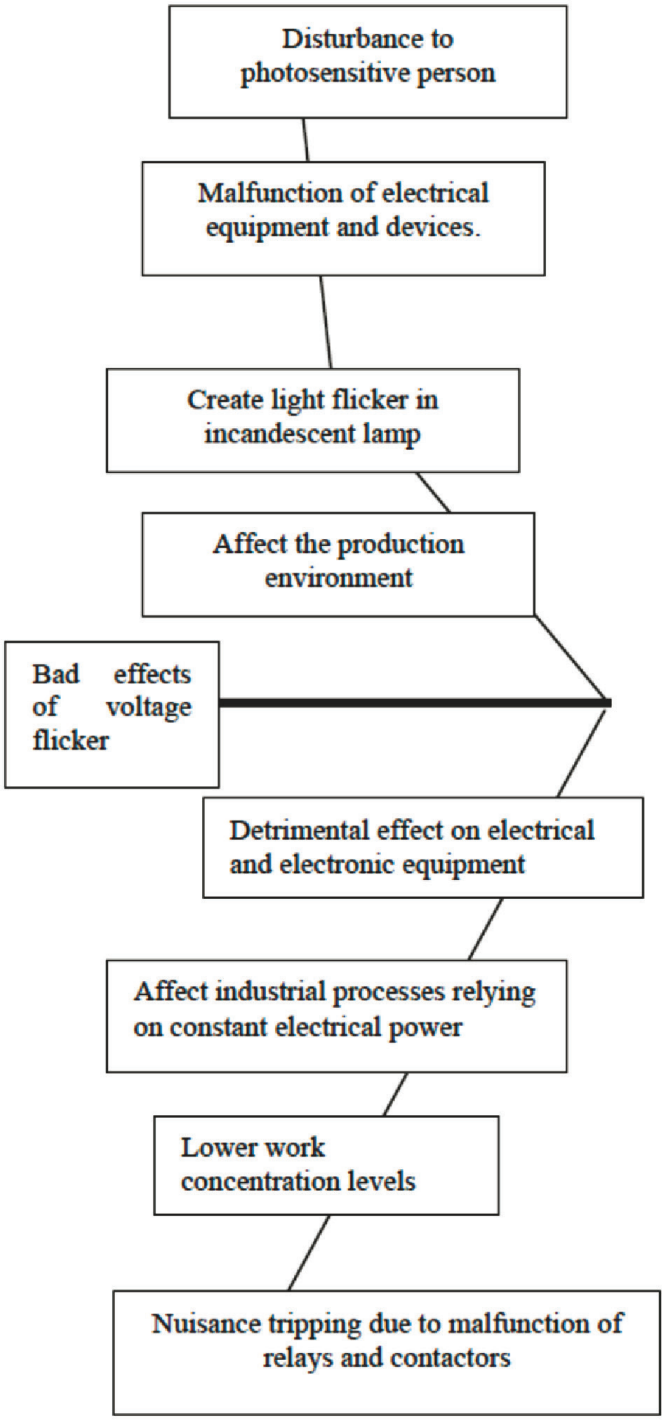

Figure 6: Bad effects of voltage flicker

Table 2
Limiting values of short term fliker emmission severity

Value	*Observation Interval*	*Limiting Value*
P_{st}	10 minutes	1.0
P_{lt}	2 hours	0.65

10. IMPACT OF VOLTAGE FLICKER ON HUMAN BEINGS.

Flicker cause irritation to the human being. The percentage of irritation depends on various factors. The amplitude of variation of voltage, frequency of variation, time period of variation are some factors on which the disturbance to the human being depends. The type of *t*.

11. MITIGATION OF VOLTAGE FLICKER.

Various methods of mitigation of voltage flicker are available. Some methods are input side mitigation methods. Some methods are output side mitigation methods.

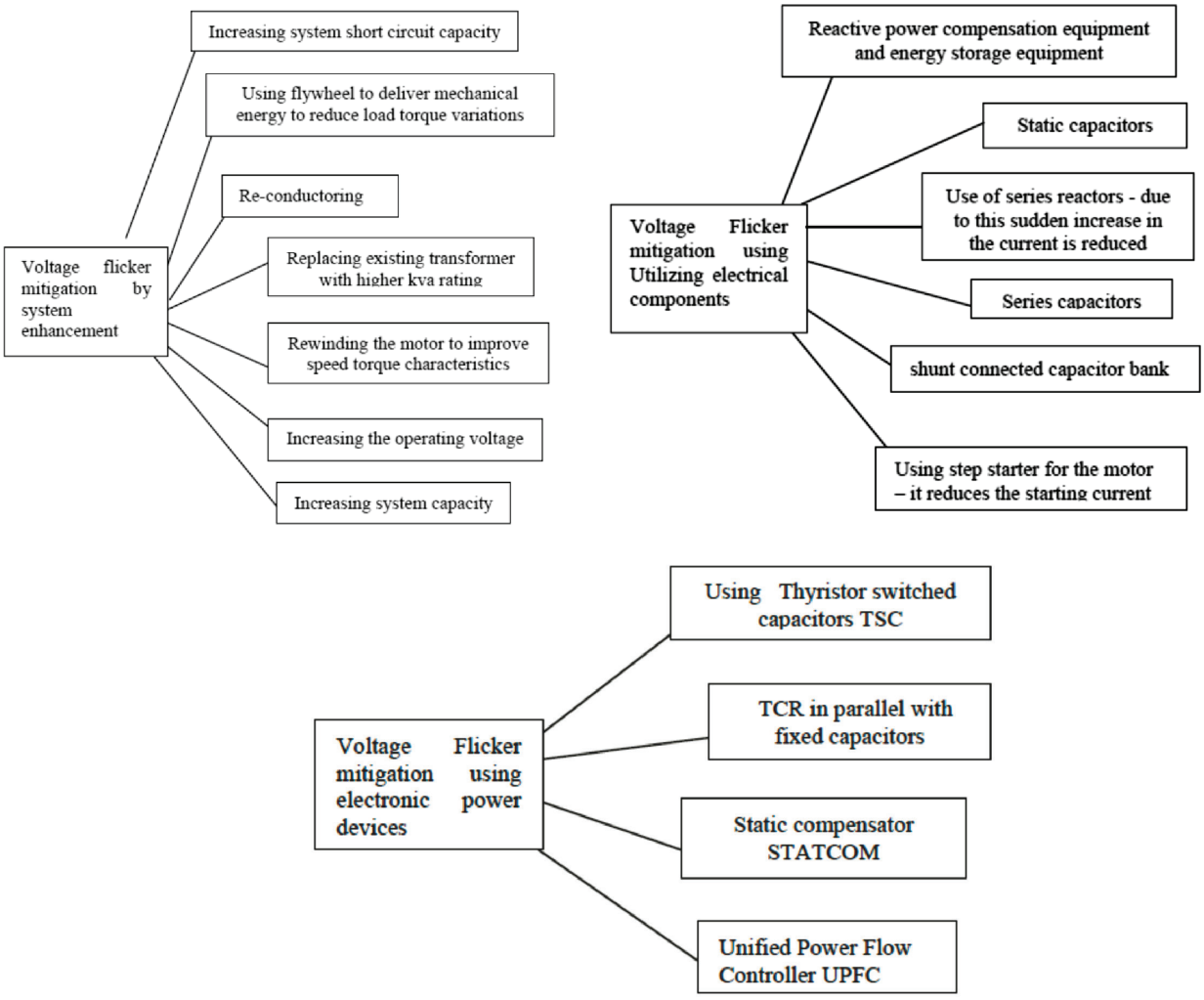

Figure 7: Voltage flicker mitigation methods of voltage flicker emmission severity

12. CONCLUSIONS

The work the person is doing is also one of the factors. The disturbance to human being also depends on the color of the light source. The disturbance from voltage flicker also varies from person to person. There is disturbance from voltage flicker while reading and watching television vision

Voltage flicker causes vomiting, disturbance and irritation. The voltage flicker causes concentration problems. The voltage flicker also causes drowsiness. High exposure to flicker may cause epileptic fits.

It is concluded that voltage flicker is a significant paramere in wind energy generation. various causes of voltage flicker and various mitigation methods of flicker are available to reduce the flicker.

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