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Impact of Renewable Energy Generation on Voltage Flicker with Dynamic Load Connected to Distribution Network

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Abstract

Voltage flicker is one of the power quality issues in a distribution network, which can occur due to voltage fluctuations as a consequence of the changes in the electrical load currents flowing through the system impedance. The effect of large loads produces voltage modulation on the line, creating noticeable changes in light intensity. Similar scenario occurs when large industrial load is switched on in a weak distribution network or where the location of such large load is far from the substation, all the customers/households around such area will experience the impact due to a rapid change in voltage, light levels tend to vary, light can dim or light up simultaneously, become noticeable and annoying. The resultant effect is known as flicker. One of the primaries aims of Renewable Energy Generation (REG) is to be installed close to the consumers or load centres. When REG is integrated into the grid near a dynamic load, its impact on voltage flicker need to be evaluated. This paper investigates the impact of Renewable Energy of Wind (using the doubly fed induction generator as a wind energy converter) on voltage flicker when large dynamic loads are connected to a local electrical distribution network. The standard Institute of Electrical and Electronics Engineers (IEEE) 13 bus network is used as test system and modelled in MATLAB/SIMULINK. The outcome showed that REG does not conduce to the voltage flicker emanated from dynamic load, otherwise, it reduces the glint. The recommendation includes: a compensator device should be installed close to the flicker affected area or near the large loads in a weak distributed network to attenuate voltage flicker and improve power quality.

Keywords: Electrical load, voltage variation, flicker, doubly fed induction generator and compensator.

1. INTRODUCTION

A set of modifications are taking position in a power system as a consequence of the launching of distributed generation. Gradually, electricity generated by fossil fuel is being replaced by electricity generated from renewable energy sources, small generator units connecting to the distribution system are replacing large generator units connected to the transmission system. The deregulation of generation, transmission, and distribution system, depending on each country has brought competition in the market [1]. The generation assets are no longer possessed by one or a few owners, but a lot of investors have entered the electricity market. People can now generate their own electricity using small combine heat and power, rooftop solar panels, and low wind energy converters to mention a few. It is obvious that all these varieties method of electricity generations will have their impact on the power system. The challenge of maintaining appropriate frequency and voltage level is increasing due to increasing interest in renewable distributed generation [2]. Power quality determines the fitness of electrical power to consumer devices. Synchronization of the voltage, frequency and phases allow electrical systems to function in their intended manner without significant loss of performance or life. Without the proper power quality, an electrical device or load may malfunction, fail prematurely or not operate at all. The power quality can be linked directly to the network itself, power flow, voltage quality and the customer connected to the distribution network. Voltage flicker is one of the power quality issues that face any local network. Why is flicker bad? For one thing, in addition to being annoying and distracting, it can cause eyestrain, blurred vision, and impairment of performance on sight-related tasks. And in those who are flicker-sensitive, it can cause debilitating headaches and migraines. 10% of the population is estimated to suffer from migraines, and that's only one of the groups prone to flicker sensitivity [3]. According to the IEEE recommended practice, flicker has been reported to contribute to autistic behaviors, and can be a trigger for epileptic seizures, although the frequencies seen in architectural products are generally above the critical range for epilepsy [3]. Some of these problems might occur even when the flicker isn't detectable by the eye. Periodic flicker can be characterized by its amplitude modulation, its average value over a periodic cycle, its shape, and its periodic frequency. And all of these characteristics affect the viewer's biological response. Flicker can also slow down text reading speed by 30%. This research paper presents an impact of a renewable energy source on voltage flicker when dynamic loads are connected to a distributed network.

2. ELECTRICAL LOAD

An electrical grid is made of interconnected network, usually electrical wires for delivering electricity from generating station to the consumers. The consumer of this generated electricity is referred to as a load. An electrical load (usually offer resistance to the flow of electricity) in its simple form is a component or part of an electrical circuit that consumes electric current or active power and absorb energy. Any load connected to an electrical grid is of three types, Resistive, Capacitive and Inductive loads. **Resistive load** converts electric current to heat energy such as incandescent lamps, electrical heaters, electric radiators etc. **Capacitive load** charges and releases energy, meanwhile capacitive reactance resists the change in voltage while allowing current to lead the voltage. Capacitive loads include synchronous motor, motor starter circuit, capacitor bank or condenser etc. Inductive load transforms electric current into a magnetic field. Inductive loads include choke, electric motor, transformer etc while Inductive reactance opposes the change to current, resulting into the grid current to lag voltage. Changes in electrical load can give rise to the change in supply voltage proportionately. Practically, when large load is switched on at home or around industrial area such as electric furnace, large motor driving machine etc, lights in most houses located around that area may dim or brighten. If large voltage changes occur in rapid sequence, light levels will change, and when the variation becomes large enough to be obtrusive or annoying, the effect is called light flicker which is a result of voltage fluctuation caused by switching of the heaviest lots. The so-called flicker is one of the power quality challenges in a distribution network that can be traced to grid voltage fluctuations.

3. VOLTAGE FLICKER

Flicker is the impression of fluctuating luminance or colour occurring when the frequency of the variation of the light stimulus lies between a few hertz. The fusion frequency of images as extensively discussed in [4, 5, 6]. Flicker is the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time as investigated in [7, 8, 9, 10]. It is considered as one of the most severe power quality problems, it is induced by voltage fluctuations, which are caused by heavy loads, such as reciprocating machines or dynamic load like electric arc furnaces (EAFs) and energisation of transformers that operate periodically in a weak power distribution system, switching of capacitors, lines, cables etc.

A small voltage fluctuation from 0.3 % to 0.5 % in the frequency range of 6-10 Hz will cause the visible incandescent lamp flickering as investigated in [11, 12]. Voltage fluctuations are systemic variations of the voltage envelope or random voltage changes, the magnitude of which does not normally exceed specified voltage ranges (0.9 to 1.1 pu as defined by ANSI C84.1-1982) [13]. Most voltage fluctuations are caused by changes in the voltage drop in the distribution system. Each part of the system has losses associated with it, and produces a voltage drop that is closely proportional to the current flowing across it. The ratio of voltage drop to current flow is called the impedance; it can be expressed as the percentage drop in voltage at rated current. Transformer impedances vary, such as, an impedance of 10% means the output voltage drop of the transformer is about 10% lower when it is fully loaded than when it has no load. Loads often change through manual switching, thermostats or changes in industrial motor loads. When a saw-mill industry's power is switched on, the current increases as the machine start operation, as it attempts to prevent the blade spinning against increased resistance, the current drops immediately when the resistance cease. Any time a load change, it affects the voltages across the electrical system for an example. When 12 horse power, 240 V wood saw-mill is switched on and draws about 60 Amp of current for 5 s and drops back to about 5 Amp at idle. The 60 Amp current momentary will increase the current draw across the grid, the magnitude of the current increase in the grid is reduced by the distribution transformer ratio. This sudden increase/reduction in current cross the grid will cause a large voltage drop that can be noticeable in the lighting bulbs and can be regarded as flicker. But when it is compared to the process of switching on/off a small load, although it can also cause a change in grid voltage, but may not be classified as flicker because it may not be seen as major disturbance as long as it is infrequent and not large enough to cause problems other than a minor perceptible light flicker. The most difficult sources of voltage flicker are large loads that fluctuate at frequencies in the vicinity of the peak sensitivity region, near 10 cycles per second. The fluctuations are erratic in the range of 1 to 15 cycles per second. For these machines to be located in a local area, far from a substation and connected to a weak distribution line, flicker may become a great concern. Meanwhile, flicker-fusion occurs within a range of about 5 to 50 Hz. Under normal steady state power conditions, most people would observe an incandescent light bulb to be emitting perfectly steady light as if the power source was direct current (DC) even on a 60 or 50 Hz system. The critical flicker frequency gradually decreases with age in adults; however, there are some differences from person to person even at the same age. Some humans can perceive visible changes in light output with as little as 0.25% changes in the root mean square (RMS) voltage that powers the light source [14]. Many techniques have been proposed in the literature for flicker-level assessment; among them the fast Fourier transform (FFT) has been used often [15, 16]. Meanwhile, this paper provides a simple, practical way of determining a voltage flicker in a distribution network and method of controlling it.

3.1 Simple way of determine flicker and control method

The most cost-effective way of dealing with flicker is to avoid it in the first place. Anytime large variable loads are added to a distribution network, there is a potential for flicker. The first level of screening is to look at the magnitude of voltage change that can occur due to load variation. This is found by multiplying the load change by the source impedance, if the maximum voltage is less than 0.2%, it is improbable that any visible flicker will happen. However, if a voltage/current monitoring device is installed, the current drawn by each load can be monitored along with the line voltage, after recording two or ten major load changes, the line voltage can be plotted against a load current. The source impedance can then be calculated, such that the change in voltage per amp of load change. Once this is accomplished, the voltage fluctuation caused by that customer can be figured from the load current fluctuations. By comparing the calculated fluctuation with the measured fluctuation, a direct measurement can be made of the percentage of the total fluctuation due to the customer being monitored. Flicker can also be measured using flicker measuring device but it may be expensive for individual to acquire. Flicker can be controlled by reducing the load changes, reducing the source impedance, and decoupling the load from lighting circuits.

3.2 Effects of Voltage Flicker on Equipment and Humans

The flicker has an indirect effect on power system which can cause a lot of havoc to both equipment and human life [17]. The abrupt regulation of the utility voltage may cause objectionable light flicker, disrupt industrial and commercial processes, and adversely affect the performance of electronic apparatus, such as computers, instrumentation, and communications equipment [18]. Light flicker perception is a physiological process in which the eye and the brain take part. Exposure to harsh fluorescent lighting can cause eye strain and blurred vision. The health effects of flicker can cause epileptic seizures, malaise, headaches and impaired visual performance [19, 20]. Voltage flicker can be mitigated with an appropriate compensator device like STATCOM, SVC etc. For a short duration, a voltage flicker waveform can be accessed mathematically as follows.

$U(t) = s(t) \sin(2\pi f_{syn} t)$ ………………………………… (1)

$$= \sqrt{2}Vms\ f(x) = 1 + \frac{1}{2}\sum \Delta V_n \mathrm{Sin}(2\pi f_n t + \varphi_n) \times \sin(2\pi f_{syn} t) \ldots$$

Where

F = Power frequency (50 or 60 Hz)

V_{rms} = Average RMS value of the voltage

ΔV_n = change in voltage

s (t) = Signal

F_n = Modulation frequency (in the rage of 0.1Hz to 30Hz)

F_{syn} = Carrier frequency

φ_n = Phase angle

The relative percentage voltage change, (ΔV %) for both phase voltage and line voltages are the same for a balanced three-phase load. It can be calculated approximately using the following equation.

$$\Delta V = \frac{\Delta P_{max}}{S_{sc}} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

ΔP_{max} = Maximum apparent power change

S_{sc} = Network short circuit power measured at the point of common coupling (PCC)

The relative voltage can be calculated more accurately using the following equation, if the active as well as the reactive part of the load change is known

$$\Delta\% = \frac{R\Delta P_{pcc1} + X\Delta Q_{pcc2}}{V^2} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where

R = Resistive part of the network impedance

X = Reactance part of the network impedance

V = Nominal voltage

ΔP_{pcc1} = Active power change of the load at PCC

ΔQ_{pcc2} = Reactive power change of the load at PCC

4. REACTIVE POWER

Volt Ampere Reactive (VAR) is the management of reactive power to improve the performance of alternating current (AC) power systems. Most power quality problems can be attenuated or solved with an adequate control of reactive power [21]. The problem of reactive power compensation is considered from two aspects, namely load compensation and potential support. **Load compensation** objectives are to increase the value of the system power factor, to balance the real power drawn from the AC supply, compensate voltage regulation and to eliminate current harmonic components produced by large and fluctuating nonlinear industrial loads. **Voltage support** is generally required to reduce voltage fluctuations at a given terminal of a transmission line. Also, to improve the voltage of the network when the grid voltage is too low because the presence of reactive power tends to increase network voltage.

4.1 Compensator

Recent improvements in power electronics have led to the availability of several different brands of static voltage compensator devices. These devices use solid-state switching of inductors or capacitors to rapidly compensate for changing line loads, thus stabilizing the grid voltage. The principle is the same as with switchable line compensation capacitors or tap changers, but they operate quickly and fast enough to reduce voltage flicker substantially. Compensator in power system means the process of a flexible voltage control at the grid or point of connection to the utility. These compensators are expensive, but they may provide a cost-effective alternative to upgrading lines when simpler remedies fail. They are categorized into three; Static synchronous Compensator (STATCOM), Static Var Compensator (SVC) and Switchable Capacitor Banks (SCB). They may be series or shunt connected to an electrical distribution system. This research paper will dwell mostly on Static compensation (STATCOM) device. STATCOM is a shunt connected reactive power compensation device that is capable of generating and/ or absorbing reactive power in which the output voltage can be varied to control the specific parameters of an electric power system [22]. STATCOM is a Voltage-Source Inverter (VSI), that converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system [23, 24]. It exhibits constant current characteristics when the voltage is low or high, under and over the limit, this allows STATCOM to deliver constant reactive power. The relation between the AC system voltage and the voltage at the STATCOM AC side terminals provides the control of reactive power flow. If the voltage at the STATCOM terminals is higher than the system voltage, reactive power will be injected from STATCOM to the system and STATCOM will work as a capacitor. When the voltage at the STATCOM is less than the AC voltage, STATCOM will work as an inductor, and reactive power flow will be reversed, when the grid voltage is equal to the STATCOM voltage, there will be no exchange of energy.

5. DOUBLY FED INDUCTION GENERATOR

Doubly Fed Induction Generator (DFG) has been receiving increasing attention due to the fact that it is more controllable and efficient, it can supply power at constant voltage and frequency while the rotor speed varies, it is not necessary to be magnetized from the power grid since it can be magnetized from the rotor circuit, the size of the converter is not related to the total generated power but to the selected speed range and hence to the slip power. In this section, modelling of doubly fed induction generator is considered.

5.1 Doubly fed induction generator modelling

The DFIG is a wound rotor induction generator, where the rotor circuit is connected to the grid through power electronic devices. The ability to supply or subtract power to or from the rotor makes it possible to operate the DFIG at sub- or super-synchronous speed, while maintaining constant voltage and frequency on the stator terminals. Thus, the DFIG is often used where variable speed, constant frequency generation is needed. The operating principle of a DFIG is based on its capability to control its speed through rotor resistance variation, that is the reason why it is wound rotor. With different values for the rotor resistance, for the same electrical power, it is possible to have different values for the speed of the machine. The control of terminal voltage or power factor by the DFIG is performed by the two back-to-back converters connected to the rotor replacing the variable rotor resistance [25]. Therefore, electrical power can be transferred through the machine's rotor, until the nominal value of the stator current is reached, the output power is thereby controlled in order to optimize the tip speed ratio of the rotor blade and to maximize the performance coefficient of the turbine. When the direct axis current is employed to control the DC link voltage constant, and quadrature axis current regulate the reactive power flow, constant output power can be achieved. The velocity control through the use of the slip energy provides the possibility of the machine to be working as a generator when the slip is positive. This is entirely possible if active power is supplied to the rotor.

The AC/DC/AC converter is divided into two components: the rotor-side converter and the grid-side converter. Grid side converter and rotor side converter are Voltage-Sourced Converters that use forced-commutated power electronic devices (IGBTs) to synthesize an AC voltage from a DC voltage source. A capacitor connected on the DC side acts as the DC voltage source [26, 27]. A coupling inductor L is used to connect the grid side converter to the grid. The three-phase rotor winding is connected to rotor side converter by slip rings and brushes and the three-phase stator winding is directly connected to the grid. The power captured by the wind turbine is converted into electrical power by the induction generator and it is transmitted to the grid by the stator and the rotor windings. The control system generates the pitch angle command (Vr) and the voltage command (Vgc) signals for rotor side and grid side converter respectively in order to control the power of the wind turbine, the DC bus voltage and the reactive power or the voltage at the grid terminals.

In recent years, the use of Variable Speed Wind Turbine (VSWT) or DFIG has become worldwide. This type of wind turbine was designed to increase the aerodynamic efficiency in various ranges of wind speeds. Their electrical system is more complex than the fixed-speed wind turbines. Better power qualities, higher amount of energy extracted and less mechanical stress on the turbines are seen as the major advantages of VSWTs. The equivalent circuit of the DFIG is shown in Figure 1.0 (a) below.

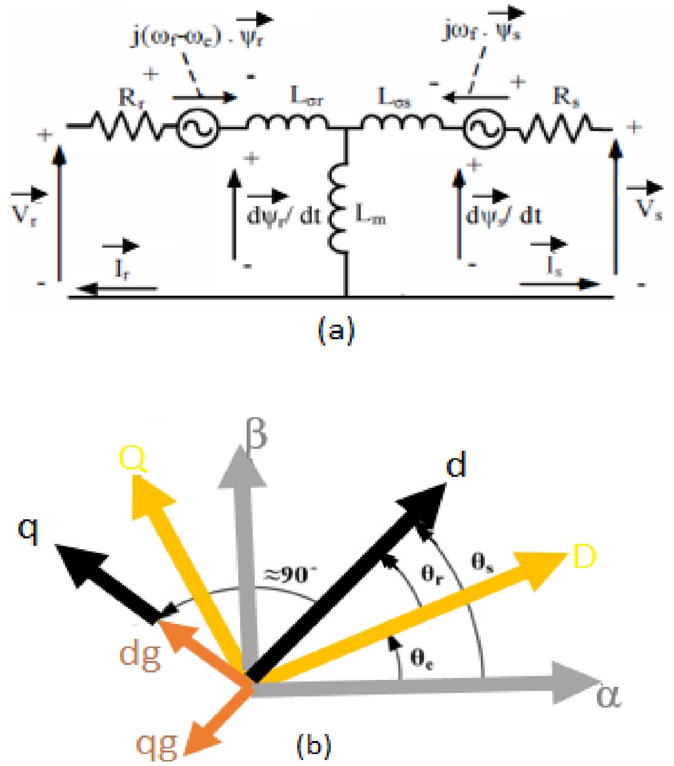


Figure 1.0: (a) Electrical model of

(b) DFIG Relation among different reference frames

There are four different reference frames in the complex plane of the DFIG system:

- Stator reference frame ($\alpha - \beta$);
- Rotor reference frame ($D{-}Q$);

- Synchronous reference frame ($d{-}q$);
- Grid voltage vector reference frame

Figure 1.0 (b) shows the relation among the aforementioned reference frames. θ_s θ_r and θ_e are the synchronous angle, the slip angle, and the electric angle of the rotor, respectively. The dg–qg reference frame is almost 90^0 ahead of the synchronous reference frame. With the relation among these reference frames, the space vector can be easily translated into any reference frame by the following mathematical equation:

$$\overrightarrow{X^{final}} = \exp(-\theta).\ \overrightarrow{X^{initial}} \quad \text{.....(5)}$$

Where θ is the angle between two reference frames, the vector of X can be represented as voltage, current, and flux.

Doubly fed induction generators consist of three-phase windings on both stator and rotor. According to the Lenz's law, the induced voltage depends on the variation of flux and turns ratio of the inducing side core. The voltage equations of the space vector for the stator and rotor are:

$$\overrightarrow{V_s^s}(t) = R_s\overrightarrow{i_s^s}(t) + \frac{d\overrightarrow{\psi_s^s}(t)}{dt} \quad \text{.....(6)}$$

$$\overrightarrow{V_r^r}(t) = R_r\overrightarrow{i_r^r}(t) + \frac{d\overrightarrow{\psi_r^r}(t)}{dt} \quad \text{.....(7)}$$

Where the superscripts "s" and "r" indicate the space vectors that are referred to the stator and rotor reference frame.

When equation (6) is inserted into (7) it becomes

$$\overrightarrow{V_r^s}.e^{-j\theta_e} = R_r\overrightarrow{i_{rs}}.e^{-j\theta_e} + \frac{d\left(\overrightarrow{\psi_r^s}.e^{-j\theta_e}\right)}{dt} \quad \text{.....(8)}$$

$$\overrightarrow{V_r^s}.e^{-j\theta_e} = R_r\overrightarrow{i_{rs}}.e^{-j\theta_e} + \frac{d\overrightarrow{\psi_r^s}}{dt}.e^{-j\theta_e} - jw_e\overrightarrow{\psi_r^s}.e^{-j\theta_e} \quad \text{...(9)}$$

$$\overrightarrow{V_r^s}(t) = R_s\overrightarrow{i_r^s}(t) + \frac{d\overrightarrow{\psi_r^s}(t)}{dt} - jw_e\overrightarrow{\psi_r^s}(t) \quad \text{.....(10)}$$

The relation between the fluxes and currents in the space vector can be expressed as

$$\overrightarrow{\psi_s^s} = L_s\overrightarrow{i_s^s} + L_m\overrightarrow{i_r^s} \quad \text{.....(11)}$$

$$\overrightarrow{\psi_r^r} = L_m\overrightarrow{i_s^r} + L_r\overrightarrow{i_r^r} \quad \text{.....(12)}$$

By substituting equation (5) into (12)

$$\overrightarrow{\psi_r^s}.e^{-j\theta_e} = L_m\overrightarrow{i_s^s}.e^{-j\theta_e} + L_r\overrightarrow{i_r^s}.e^{-j\theta_e} \quad \text{.....(13)}$$

$$\overrightarrow{\psi_r^s} = L_m\overrightarrow{i_s^s} + L_r\overrightarrow{i_r^s} \quad \text{.....(14)}$$

Solving the $\overrightarrow{i_s^s}$ and $\overrightarrow{i_r^s}$ by using the equation (11) and (14), it becomes

$$\overrightarrow{i_s^s} = \frac{L_r\overrightarrow{\psi_s^s} - L_m\overrightarrow{\varphi_r^s}}{L_sL_r - L_m^2} \quad \text{.....(15)}$$

$$\overrightarrow{i_r^s} = \frac{L_s\overrightarrow{\psi_r^s} - L_m\overrightarrow{\varphi_s^s}}{L_sL_r - L_m^2} \quad \text{.....(16)}$$

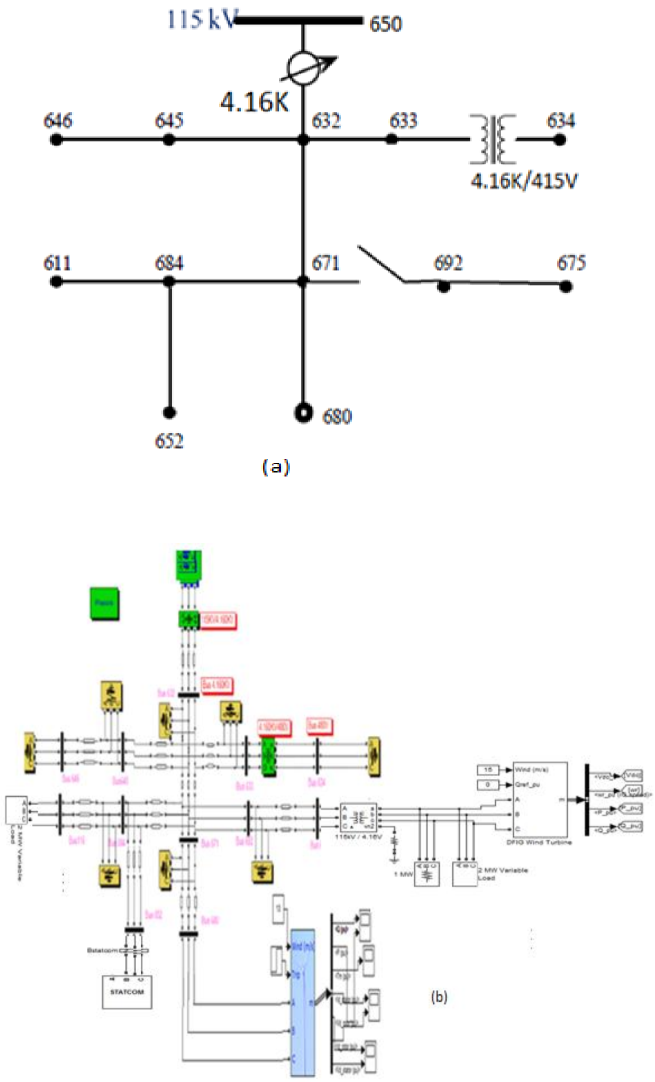
Replacing (15) and (16) with (6) and (10), respectively, yields the state equations of DFIG, as follow:

$$= \frac{d\overrightarrow{\psi_s^s}}{dt} = -\frac{R_sL_r}{L_sL_r - L_m^2}\overrightarrow{\psi_s^s} + \frac{R_sL_m}{L_sL_r - L_m^2}\overrightarrow{\psi_r^s} + \overrightarrow{V_s^s} \quad \text{.....(17)}$$

$$= \frac{d\overrightarrow{\psi_{rq}^s}}{dt} = -\frac{R_rL_m}{L_sL_r - L_m^2}\overrightarrow{\psi_s^s} + \left(jw_e\frac{R_rL_s}{L_sL_r - L_m^2}\right)\overrightarrow{\psi_r^s} + \overrightarrow{V_r^s} \quad \text{.....(18)}$$

6. TEST SYSTEM MODELLING

The test system under study is IEEE 13-bus test system [28]. It is modified and modelled in MATLAB/SIMULINK as shown in Figure 1.1 (a) and (b). The network is simulated for 0.5 seconds and the reference voltage is maintained at 1.00 pu in Figure 1.1 (c).



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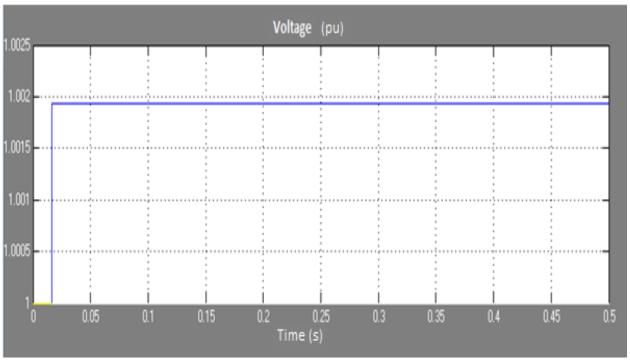

Figure 1.1: (a) IEEE 13 Bus (b) Equivalent circuit in MATLAB/SIMULINK (c) Grid voltages without dynamic load

6.1 Impact of Dynamic load in a distribution network

When dynamic load such as electrical arc furnace is connected to the network, the parameters are shown in Appendix. The network is simulated for 0.5 seconds and the reference voltage is still maintained at 1.00 pu. Figure 2 shows the variations in grid active, and reactive power (1st trace blue and green colour) as well as grid voltages (trace 2) is more than 2 %. The grid voltages fluctuate between 0.96 pu and 1.04 pu (+/- 4 % variation), this voltage variation is as a result of switching on of large dynamic load connected to the network.

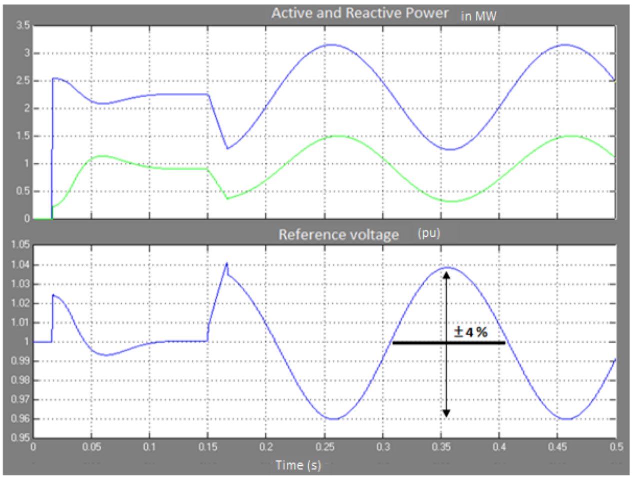

Figure 2: Active, reactive power and reference voltage with dynamic load

6.2 Impact of REG on voltage flicker

Generation of voltage flicker due to the connection of dynamic loads is discussed in the section above, in this section; the impact of the REG on voltage flicker with dynamic load connected is investigated. REG is connected at the point of common coupling in the network and set to the voltage control mode, simulation process is repeated for 5 seconds, the results are depicted in Figure 3 below. It is observed that the reference voltage improved from 1.00 to 1.05 pu with REG integration as shown in the second trace first line, and voltage flicker has reduced from ± 4 % to ± 1 % as depicted in Table 1.

Table 1: Voltage flicker variation analysis

	Reference voltage (pu)	Voltage variation (pu)	Difference (pu)	Total flicker variation
Dynamic load	1.00	1.04	0.04	4%
	1.00	0.96	0.04	
Dynamic load + REG	1.05	1.06	0.02	1%
	1.05	1.04	0.01	
Dynamic load + REG + Compensator	1.05	1.05	1.05	0 %

The connection of REG to a distribution network reduces voltage flicker which is in agreement with the research work done in [29], by strengthening the grid and increasing the integration of REG in a weak distribution network can minimise the flicker emission.

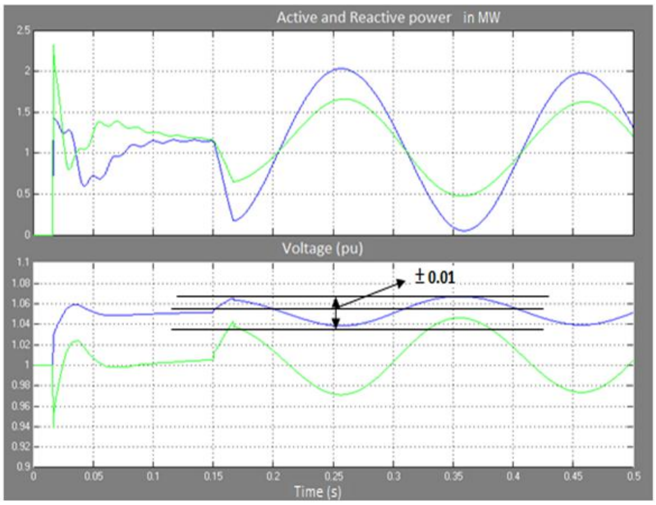

Figure 3: Active, reactive power and reference voltages with dynamic loads and REG integration

6.3 Dynamic load versus REG versus compensator

When a compensator (STATCOM) is installed in the network at the point of common coupling (PCC), there is an improvement in the grid voltage stability. STATCOM regulates the grid voltage by absorbing or generating reactive power while maintaining 1.05 pu as shown in the Figure 4 second trace blue colour, the voltage flicker is eliminated, the STATCOM compensates for the voltage fluctuations by injecting reactive currents modulated as shown in the Figures 4 third trace and Figure 5. The STATCOM varies between 0.6 pu capacitive when voltage is low and 0.6 pu inductive when the voltage is high as depicted in Figure 6 (second trace).

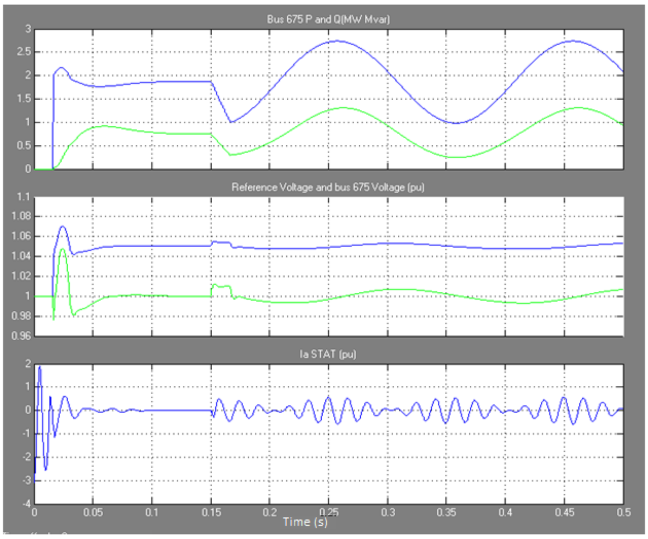

Figure 4: Active, reactive, reference voltage and STATCOM modulated current

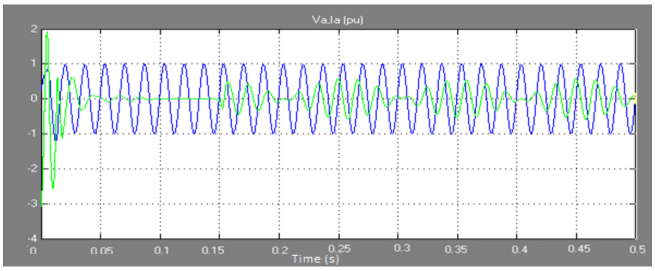

Figure 5: STATCOM modulated voltage and current

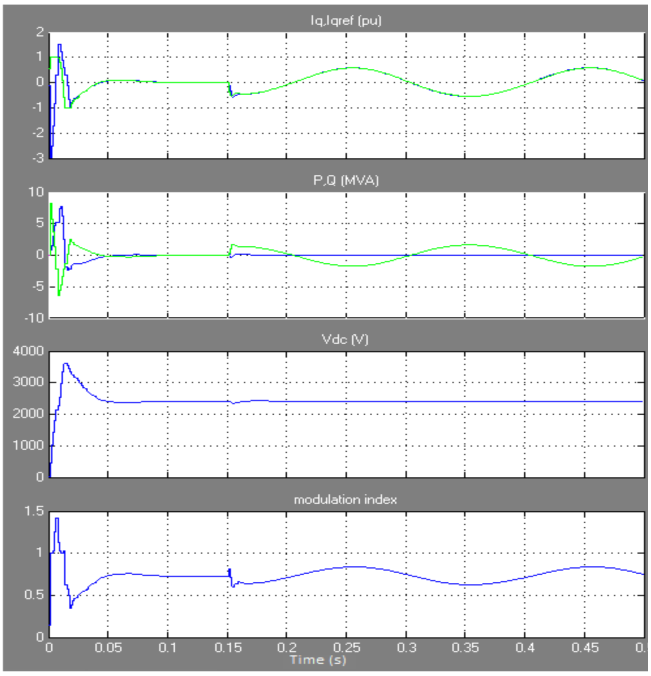

Figure 6: STATCOM controller wave forms

7. CONCLUSION

Sudden variations in the luminosity of light level due to a sudden change in voltage can certainly attract attention in homes. This paper has demonstrated the effect of connecting dynamic load to a weak distribution network, which can cause light flicker as a result of grid voltage fluctuations. The paper not only studied the perception process, but also the conversion of electricity into light, because the output level of an ampliace/lamp depends on the power supply voltage. Different lamp types (incandescent, fluorescent, arc lamps) respond differently, but in general the light output is proportional to the power consumption, although the power is not necessarily relative to the voltage. In ballasted lamps, such as arc lamps and fluorescents, the ballast stabilizes the power, which is therefore more or less proportional to the voltage. Incandescent lamps act like resistors, so the power is approximately proportional to the square of the voltage. As a result, incandescent lamps tend to be the most sensitive to changing voltage. The recommendation includes: Renewable energy generation should be integrated into a weak area where voltage variation/flicker is paramount. Also, flicker can be detected by monitoring, measurement and calculation through the source impedance. By installing compensator devices close to dynamic loads, voltage flicker can also be mitigated. The recommendation of this research paper is very important for utility and private owned power generation companies since it showcases the effect of connecting dynamic load to a weak distribution network. İt also revealed the contribution of integrating renewable energy to distribution network, which decrease voltage flicker and the purpose of using a compensator device in a flicker affected areas.

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APPENDIX

Table 1: Dynamic load parameter

Dynamic load	
Nominal load and p.f	2.2e6 and 0.9
Modulation: Amplitude (Arms) Frequency (Hz)	2000 5
Modulation timing : [Ton Toff]	[0.15 1]*100
Nominal voltage (V)	4.160

Table 2: Data for DFIG

Rated power	2 MVA
Power factor	0.98
Voltage	4.16 kV
Frequency	50 HZ
Stator resistance	0.00706 Ω
Stator inductance	171 mH
Magnetizing inductance	2.9 H
Rotor resistance	5m Ω
Rotor inductance	156 Mh
Pole pair	0.013
Converter parameter	
Converter maximum power	0.5
Grid side coupling inductor	0.15 pu
Grid side coupling resistance	0.0015 pu
Nominal DC bus capacity	1000 μF
Nominal DC voltage	1200 V
Coupling inductor current	[0 90]
Voltage regulator parameter	
Grid voltage ref	1.0 pu
Grid side converter ref	0
Grid voltage regulator k_p	1.25
Grid voltage regulator k_i	300
Droop	0.03