# Impact of Voltage Fluctuate, Flicker and Power Factor Wave Electric Generator to Local Distribution

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***Abstract*—Electricity is the most powerful energy source in the world. Engineer and technologist have combined and cooperated to invent a new low-cost technology and free carbon emission where the carbon emission issue is a major concern now due to global warming. Renewable energy sources such as hydro, wind and wave are becoming widespread to reduce the carbon emissions. On the other hand, this effort needs several novel methods, techniques and technologies compared to coal-based power. Power quality of renewable sources needs in-depth research and endless study to improve renewable energy technologies. The aim of this project is to investigate the impact of the renewable electric generator on its local distribution system. The power farm was designed to connect to the local distribution system and it will be investigated and analyzed to make sure that energy which is supplied to the customer is clean. The MATLAB tools are used to simulate the overall analysis. At the end of the paper, a summary of identifying various voltages fluctuates data sources are presented in terms of voltage flicker and a suggestion of the analysis also presented for the development of wave generator farms.**

***Index Terms*—Flicker; Carbon Emissions; Power Factor; Voltage Fluctuate; Renewable energy.**

## I. INTRODUCTION

In the early 17th century the coal technology was established to operate the vehicle steam engine and factories. At that moment, the train was used for the public transport. The coal was used to fire up to high temperatures as heat energy for boiling water to generate steam. The steam flowed and moved locomotive engines, steamboats and factory machines [1]. Nowadays steam technology is very popular in heavy industries and other applications: in hospitals, the steam is supplied to autoclave pressure chamber to eliminate the bacteria in the sterile process. In a nuclear power plant, the heat from the radiation source is used for heating the water to produce the steam. The steam is used to move the propeller to electrical energy.

Then, in late 20th century, the carbon emissions became a big issue in the world due to the climate changes attributed to the burning of fossil fuel. Much study has been done by scientists and showed the greenhouse gases effects to be immense. One of the major problems was that it made the ozone layer so thin that important barrier to solar radiation was lost, resulting in a substantial temperature increase. With growing awareness of climate issues, the developed countries began to look for the new resources for alternative sources. The new resources must not pollution in the world [1]. The purpose of new resources is to reduce the green gas emissions to the environment. Due to the impossibility of reducing humanity's insatiable demand for energy, renewable energy is the only solution to reduce carbon emissions in the world. What is renewable energy? Renewable energy is derived from infinite natural sources that are never finished and exist all the time, such as the wind, rain, the sun, wave, tidal and geothermal heat. The Earth is filled with renewable energy resources for electrical power generation. Ocean wave energy is one of the most promising potential sources of clean renewable energy due to the inevitability of the tidal system, which demands only the presence of the ocean and the moon's gravitational influence of the sea, unlike solar and wind energy which are more erratic (e.g. due to storms, clouds and irregular winds).

The renewable energy electrical generation plant having the same problems with conventional generation plant (using gas or coal). Voltage problems such as voltage fluctuate and voltage flicker can affect electronic devices and annoying to human [2]. This is because the equipment is designed with a limited capacity. If the power supply supplied to consumers is unstable and the event occurs quite often, it will interfere with the operation of the equipment and may damage the equipment. Some effects such as voltage flicker are not dangerous to the users, but they are disturbing to the sight and comfort of the consumers. However, if voltage instability occurs frequently, such as over voltage, under voltage and voltage fluctuates, it will damage the equipment and can be very dangerous to the user, especially if it happens to equipment that has a direct correlation with humans such as biomedical devices. In this research, the impact of the renewable electric generator to its local distribution will be identified and investigated for future technology.

## II. MODELING THE RENEWABLE ELECTRIC GENERATOR TO LOCAL DISTRIBUTION

The block diagram of renewable electric generator connecting to local distribution is shown in Figure 1.

The wave energy converter is a system that captures ocean wave energy and converts electrical energy. AC-DC-AC converter was used as a controller to stabilize the power and provides the quality power to the local distribution. Before transmitting the power to local distribution, the power

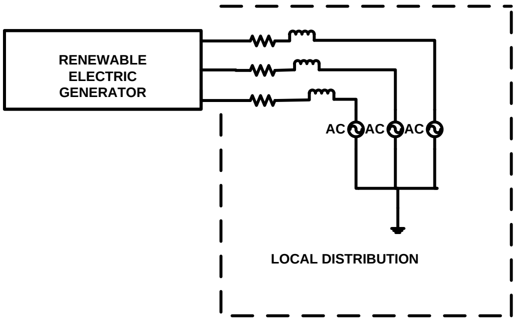


Figure 1: Model of renewable electric generator to local distribution

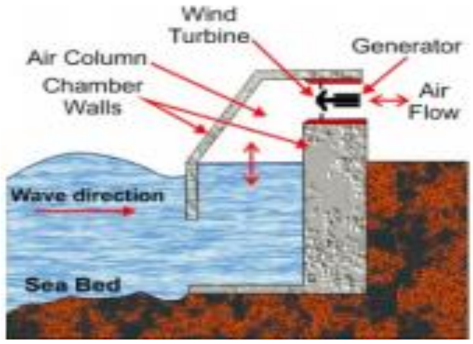


Figure 2: Oscillating water column [4].

provider has to ensure safe and follows the customer requirement.

A few types of wave energy converters have been developed and many companies provide the design service of wave energy converters around the world.

Table 1 shows the device renewable energy (wave power station) contains descriptions of capture method [4]. Many methods have been developed and were commercialized. One of the earliest methods to capture the wave before converting to the electrical energy is via an oscillating water column. Figure 2 shows that between the turbine and the sea water is a gap that we called air column [4]. The ocean wave makes the water level in air column is rise and fall. When the water level is raised up, the air pressure in the water column will increase and cause the air in the water column to have a high pressure which allows the turbine rotated in the same direction of the air flow. When the water level drops, the air in the column is depressed due to the air from the atmosphere flowing in the reverse direction into the air column, thus the turbine rotates in reverse rotation. A generator has two turbines to rotate the generator in forward and reverse direction. The development of the wave capture method is real based on mechanical parts. Hydraulic and shaft technology may produce more power to convert the mechanical energy to electrical energy.

Table 1
Comparison of Renewable Devices [3]

| Device | Power take off | Capture method |
|---|---|---|
| Anaconda wave energy converter | Hydroelectric turbine | Surface-following attenuator |
| AquaBuOY | Hydroelectric turbine | Buoy |
| AWS-iii | Air turbine | Surface-following attenuator |
| CETO wave power | Pump-to-shore | Buoy |
| Crestwing | Mechanical | Surface-following attenuator |
| Cycloidal wave Energy converter | Direct Drive Generator | Fully submerged Wave termination |
| FlanSea (Flanders Electricity from the Sea) | Hydroelectric turbine | Buoy |
| Islay LIMPET | Air turbine | Oscillating water column |
| Lysekil Project | Linear generator | Buoy |

Figure 3 shows another popular design in the market which is the bulge wave. Bulge wave technology is a long rubber tube of approximately 200 meters. The head was mounted to the seabed and the tail is connected to the generator. This rubber tube consists of filled water. The ocean wave makes the bulge move along the tube from head to tail with the energy that drives the turbine rotated. It is also known as a giant snake [3].

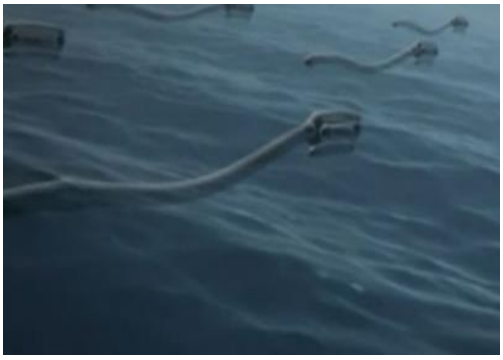

Figure 3: Bulge Wave [3]

## III. CAD SIMULATION CONTROL STRATEGY

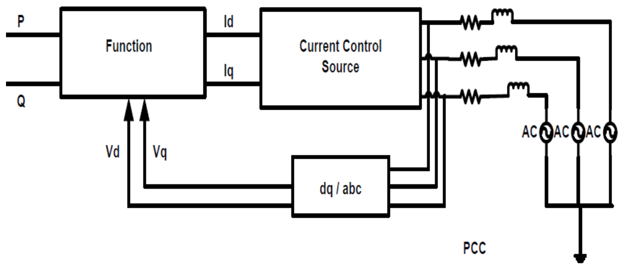


Figure 4: WEC to local distribution block diagram

Figure 4 shows the P and Q symbol is active power and reactive power generated from wave energy. The function is a mathematical model for the $P_a$ and Q. The function block is a P and Q combination with d and q. The mathematical function is shown in Equation (1) [5].

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} V_d & V_q \\ -V_q & V_d \end{bmatrix}^{-1}\begin{bmatrix} P_a \\ Q \end{bmatrix} \quad (1)$$

In the matrix, if the $A=\begin{bmatrix} a & b \\ c & d \end{bmatrix}$, then the inverse of a matrix is given by $A^{-1}=\frac{1}{ad-bc}\begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$ where $ad-bc\neq 0$, if $ad-bc=0$, then A is singular, matrix A has no multiplicative inverse. Therefore the [1] is where;

$$i_d = \frac{2}{3}\left(\frac{V_d}{V_d V_d + V_q V_q}\right)(P_a) - \frac{2}{3}\left(\frac{V_q}{V_d V_d + V_q V_q}\right)(Q) \quad (2)$$

$$i_q = \frac{2}{3}\left(\frac{V_q}{V_d V_d + V_q V_q}\right)(P_a) + \frac{2}{3}\left(\frac{V_d}{V_d V_d + V_q V_q}\right)(Q) \quad (3)$$

The equations of $i_d$ and $i_q$ have written in the function block and the output of the function is connected to the current controller sources [5]. The current controller source is to observe the input, from wave energy converter output and give the feedback response to the input to control the output. It has to do be done to get the maximum output before it is connected to the local distribution.

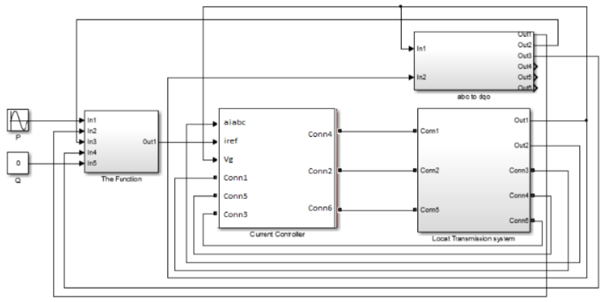


Figure 5: MATLAB simulation block diagram.

Figure 5 shows the Matlab simulation block diagram. P and Q are active power and reactive power from the generator. The current controller source functions to observe the input, from wave energy converter output and give the feedback response to the input to control the output before transmitting to the transmission system. In the block transmission system, it was used to observe the voltage, current and flicker occurring while transmitting the power.

## IV. SIMULATION EXPERIMENT

The simulation begins with controlling the input power contain active power and reactive power. By controlling the input power, the output is observed and records at the point of common coupling (PCC). The local distribution sets up parameter also is changed to observe the effect on the output. The concept of free simulation is applied to this simulation. It means the simulation input setting was built in several ways to observe the impact at the PCC.

This simulation is the focus for instantaneous flicker sensation that the testing is done in ten minutes (600 seconds). The input voltage is measured in RMS value. To ensure the RMS value is right, the RMS meter is measured directly to the circuit (PCC) using the RMS meter tools. Most of the signal used is a constant signal (constantly fluctuate). The impedance is used is large impedance R = 0.9 and L= (0.00328) and observe the PCC if the load is changing.

## V. SIMULATION RESULT

The first simulation, the active power (P) and reactive power (Q) were set up to zero. The result is the power is not produced, the generator stops, the voltage at PCC has been always same as the transmission voltage setup. It is very dangerous if the protection is provided to prevent the voltage flowing back to the generator, which would harm the entire electronic devices. The protection such as a breaker to isolate the power from the transmission line to the generation division must be available to protect the ring connection. The ring systems connect all the load, distribution power and transmission power together. They share the power together. The advantage is, if the power is not sufficient for the momentary need in some places due to high-consuming power or high load, the distribution agency can ask the generation division to produce some power from another generation to top up the power at another place. However, the ring system must have the isolation system. If the generator stops supplying the power during high demand, it will make the other generator work under load and the system will shut down or the generator will shut off to protect the system. If this occurs, what will happen? It will shut off all the generators which connected to the grid system and can make the whole country shut down as well. It is absolutely very dangerous to the country, especially in military, transportation and so on. It will become a total disaster. To protect this, the system is isolated from the grid to ensure under load power does not occur. Figure 6 shows the ring systems and how to isolate the generator from the ring grid. If the generator A is under load, generator B can top up the demand power from local area A. However, if the generator A is shut down due to the system damage, it leaves local area A load without support power from another side. The generators B, C and D must be isolated from A otherwise, they can collapse or shut down due to the overload.

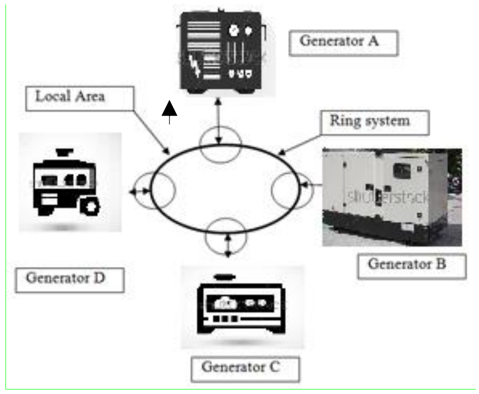


Figure 6: The ring system.

Second simulation, the active power, P is set up constant, and the amplitude, Amp of active power is increasing constantly. Besides that, the reactive power, Q also increases to see the effected waveform. The reactive power, Q is affected by the power output. When the input reactive power Q is zero, it looks like no coil or capacitor in the systems and the circuit is purely resistive, (Z = R + j0) or zero inductance/capacitance. The voltage waveform and current waveform are in phase. After increasing the reactive power, Q the voltage waveform and current waveform start shifting (out phase). The shifting angle is increasing along with the reactive power, Q, manifesting inductance or capacitance. The phase angle is different due to the capacitance in the generation for this simulation that makes the current wave form leading.

In Table 2, when the Q is increasing from 200 watts, 500 watts to 1000 watts showed the power factor is decreasing. In the distribution system, the inductance from transformers, motors, etc. make the current lag. Adding the capacitors bring the current back in phase with the voltage. Therefore, in the customer distribution station, the capacitor bank is installed to correct the power factor. The power factor closest to 1 is the best to have maximum power [6]. The output power used appears smaller when decreasing the power factor. It draws more current but uses less. This will harm the neutral cable where most energy will convert to heat. Therefore, the power provider/authority has regulated the power factor to ensure it does not allow lower than 0.8 at a certain time [6], if the

Table 2
Simulation Result 2

| SUBJECT | $V_{max}$ | $V_{min}$ | $V_{max}$-$V_{min}$ | %ΔV/V | Power Factor | Power | $P_{st}$ | RMS |
|---|---|---|---|---|---|---|---|---|
| P=0, Amp=0, Q=0 | 325.26 | 325.26 | 0 | 0 | 1 | 0 | 0 | 239.3 |
| P=1000w, Amp=0, Q=0 | 327.1 | 327.1 | 0 | 0 | 1 | 340.5 | 0 | 240.5 |
| P=1000w, Amp=200w, Q=0 | 327.5 | 326.75 | 0.75 | 0.2306 | 1 | 375.3 | 0.17 | 240.6 |
| P=1000w, Amp=500w, Q=0 | 328.1 | 326.2 | 1.9 | 0.5841 | 1 | 427.8 | 0.39 | 240.8 |
| P=1000w, Amp=1000w, Q=0 | 329 | 325.2 | 3.8 | 1.1683 | 1 | 515.5 | 0.77 | 241.1 |
| P=1000w, Amp=0, Q=200w | 326.73 | 326.73 | 0 | 0 | 0.999 | 273.6 | 0.072 | 240.2 |
| P=1000w, Amp=0, Q=500w | 326.12 | 326.12 | 0 | 0 | 0.9991 | 173.8 | 0.077 | 239.7 |
| P=1000w, Amp=0, Q=1000w | 325.1 | 325.1 | 0 | 0 | 0.9972 | 9.038 | 0.079 | 238.8 |

**Amp is referring to amplitude of power fluctuation.

power factor is reduced below than the permitted acceptable level, a penalty/fine will be charged to the customer. This is to protect the transmission and other customers.

An analogy for the voltage and current is like two people riding a bicycle and both of them are paddling at the same time. If one of them does not paddle at the same time, then the bicycle moves slowly but if they do paddle at the same time, the bicycle will move very smoothly and quickly. The voltage and current also work on the same concept. In the observation, no impact of voltage fluctuation and voltage flicker was detected. Increasing the Q value was not affect flicker. The reactive power does not affect voltage fluctuations, but it does affect the power factor whose efficiency is reduced due to the voltage and current not being in phase. Basically, flicker does occur due to voltage fluctuations. If the voltage does not fluctuate, it has no flicker.

Table 3
Simulation Result 3

| SUBJECT | $V_{max}$ | $V_{min}$ | $V_{max}$-$V_{min}$ | %Δ V/V | Power Factor | Power | $P_{st}$ | RMS |
|---|---|---|---|---|---|---|---|---|
| P=25kw, Amp=0, Q=0 | 375.33 | 375.33 | 0 | 0 | 0.9999 | 1.057E+04 | 0 | 270.8 |
| P=25kw, Amp=100w, Q=0 | 375.54 | 375.12 | 0.42 | 0.111 | 0.9999 | 1.060E+04 | 0.08 | 270.9 |
| P=25kw, Amp=200w,Q=0 | 375.75 | 374.9 | 0.85 | 0.226 | 0.9999 | 1.063E+04 | 0.16 | 271 |
| P=25kw, Amp=300,Q=0 | 375.96 | 374.7 | 1.26 | 0.335 | 0.9999 | 1.065E+04 | 0.23 | 271 |
| P=25kw, Amp=400w,Q=0 | 376.2 | 374.5 | 1.7 | 0.452 | 0.9999 | 1.068E+04 | 0.31 | 271.1 |
| P=25kw, Amp=600w,Q=0 | 376.6 | 374.06 | 2.54 | 0.676 | 0.9999 | 1.073E+04 | 0.47 | 271.3 |
| P=25kw, Amp=800w,Q=0 | 377 | 373.6 | 3.4 | 0.905 | 0.9999 | 1.078E+04 | 0.62 | 271.4 |
| P=25kw, Amp=1000w,Q=0 | 377.4 | 373.2 | 4.2 | 1.119 | 0.9999 | 1.083E+04 | 0.77 | 271.5 |
| P=25kw, Amp=1500w,Q=0 | 378.5 | 372.2 | 6.3 | 1.678 | 0.9999 | 1.096E+04 | 1.17 | 271.9 |
| P=25kw,Amp=2000w Q=0 | 379.5 | 371.1 | 8.4 | 2.238 | 0.9999 | 1.109E+04 | 1.55 | 272.2 |
| P=25kw, Amp=10000w,Q=0 | 397 | 354.5 | 42.5 | 11.32 | 0.9999 | 1.322E+04 | 7.53 | 277.8 |
| P=25kw,Amp= No constant, Q=0 | 390 | 360 | 30 | 7.993 | 0.9999 | 1.056E+04 | 2.73 | 270.8 |
| P=25kw,Amp=800w, Q=400w. | 376.3 | 372.9 | 3.4 | 0.905 | 0.9999 | 1.064E+04 | 0.62 | 270.8 |
| P=25kw,Amp=800w, Q=2000w. | 375.5 | 370.1 | 5.4 | 1.438 | 0.9999 | 1.008E+04 | 0.67 | 268.4 |
| P=25kw,Amp=800w, Q=0,F=1 kHz | 377 | 373.6 | 3.4 | 0.905 | 0.9999 | 1.047E+04 | 0.37 | 270.5 |

**Amp is referring to amplitude of power fluctuation.

The third simulation, the input active power, P is constantly setting, but the amplitude fluctuation is constant and non-constantly increase to see the effect of constant and non-constant amplitude fluctuation. Also, the reactive power, Q is increased to observe the waveform at PCC. In simulation 3, the power is greater than in the simulation 2. A model of 25kW generator installed in Alaska by ORPC (Ocean Renewable Power Company) company was chosen [7].

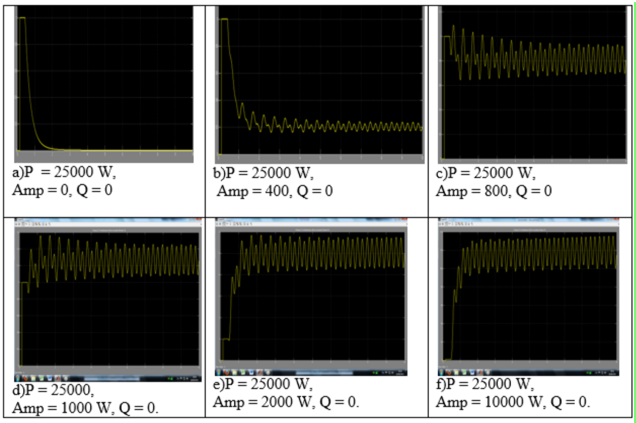


Figure 7: Instantaneous flicker sensation increase when the fluctuation increases

Table 3 shows the data recorded for the whole of third simulation and Figure 7 displays the instantaneous flicker sensation waveform. During the observation, higher voltage fluctuation produced a higher instantaneous flicker sensation. Higher instantaneous flicker sensation produces higher $P_{st}$ results (when Vmax-Vmin is 42.5) but the power factor was not affected the voltage fluctuation. The $P_{st}$ is a measure of irritation. It is not an absolute measurement of voltage or of voltage modulation. One may not notice that the 100 small flickers in the lights (under the $P_{st}$ threshold) but one would notice the one big flicker (over the $P_{st}$ threshold). Each time we switch on a kettle (for instance), that is ONE voltage change. So ON and OFF is TWO voltage changes. As $P_{st}$ increases, the power fluctuation also increases.

The IEC standard measured that the $P_{st}$ should be under 0.8 and $P_{lt}$ is 0.65 [8]. $P_{st}$ or $P_{lt}$ gives an idea of how badly flicker affect the eyes and brains [9]. $P_{st}$ or $P_{lt}$, when computed according to the standards, show to the utility companies (for example) whether voltage fluctuations on their networks might cause a problem with flicker and if it needs to be fixed or not. Instantaneous flicker sensation helps us to work out where the problem is originating. Instantaneous flicker sensation shows us whether it is 1000 small voltage fluctuations in a minute or just one big one, and how it might depend on the shape of the fluctuations.

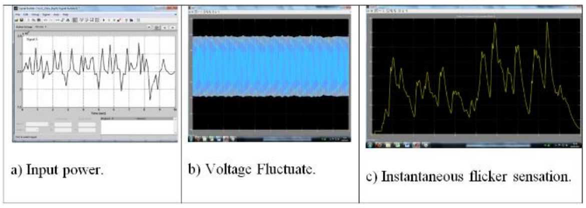


Figure 8: Non-constant power fluctuation

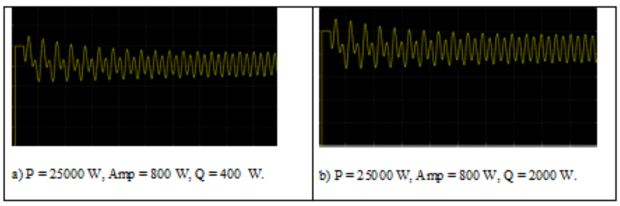


Figure 9: Power fluctuation with increase Q value

Figure 8, it can be seen that the input power was not the constant fluctuation and we can see the $P_{st}$ is increasing. The constant fluctuation for the P=25kw, Amp=0W, Q=0 is zero ($P_{st}$) only but for non-constant fluctuation, the $P_{st}$ value is 2.73. The power factor is constant whether the amplitude is constant or non-constant. Non-constant fluctuation might make the magnitude of amplitude increase suddenly and either lower or higher will make the instantaneous flicker sensation and generated $P_{st}$ high.

Figure 9 shows the increase in the Q value from 400 watts and 2000 watts in constant. The constant power does not really affect the $P_{st}$ because it does not make the voltage fluctuate but it reduces the power. The power factor not really seen to reduce due to the 25000 watts being very high if compared to the Q value (400 watts and 2000 watts), but the output power showed it reduced from 10,600 watts to 10,080 watts. Again, the conclusion is that the fluctuation affects the flicker, but the capacity of power (either P or Q) was not affected to the voltage flicker. The power fluctuation also does not affect to the power factor.

## VI. CONCLUSION

This paper presents the simulation results that show the active and reactive power does not affect the flicker however affected the power efficiency. Increasing the power capacity in constant also does not affect the voltage fluctuations and voltage flicker. In fact, the power fluctuation is effect to the power flicker. Reactive power reduced the power factor. In this case, the system design should minimize the reactive power and correct the waveform before transmitting to the transmission line as to maximize the power, by bringing up the power factor close to 1 using the effective capacitor bank.

Designing the generator station as close as possible to the grid (longer distance = higher power losses), using high quality components and materials with low resistance to maximize the power and design the active filter to control the waveform using the IGBT/SCR with high-speed switching and high frequency is one of the best solutions to reduce the power lost and harmonic distortion [11].

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