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Performance Analysis of Isolated Hybrid System Model on Dynamic Load State *(Pre-Generator, Generator and Post-Generator)*

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ABSTRACT

A Hybrid Power Plant Diesel Generator with Renewable Energy Resources Power Plant is one of the solutions for supply electric demand to isolated area. The energy sources that can be used for hybrid system are such as photovoltaic, wind, and biomass or biogas, because these sources are almost available in every isolated area. This research used a model of hybrid system from diesel generator and 1.5 kWp photovoltaic power plants. The reliability and some of power quality issues of this system tested by 1300VA house hold daily load characteristic effectively 24 hour. Power quality and some electricity parameters during transition mode will be analyze. Furthermore the power quality analyze will be conducted and evaluated base on Electrical Engineers' Association (EEA).

KEYWORDS: hybrid power plant; photovoltaic power plant, isolated system; distributed generation; reliability; power quality; harmonic

PREFACE

Nowadays the electricity system developments and integrations in Indonesia still focus on big islands. For small or remote islands still have separate electricity systems, even though some islands already interconnected with sea cable transmission line. Sea cable transmission line needs very high investments cost. To reduce the investment cost and to maximized the fulfill electricity needs in Indonesia, the right electricity generations and distribution technology must be done.

Most of islands in Indonesia still used Diesel Generators as electricity source. Due to high cost off diesel engine, the electricity cost at remote islands become expensive. To reduce the dependence on fossil energy source, its need to develop a hybrid power plan base on available energy resources at that location, especially renewable energy resources.

In Indonesia the potential of renewable energy, especially solar energy is very abundant because almost all regions in Indonesia can be exposed to the sun throughout the year. Nevertheless, electricity from solar energy does not necessarily directly replace electricity from fossil energy because the nature of renewable energy is generally intermittent or not fixed and is highly dependent on natural conditions. Therefore, the development of diesel generator hybrid system with Solar Power Plantor Photovoltaic (PV) in the archipelago areas is necessary.

The PV-Diesel hybrid system is potential to be developed in isolated islands but technical analysis in terms of the power of this system has not been done. That's why we need to do some research on the power quality of the PV-Diesel hybrid system. Intermittent source is known to be a cause of power quality disruption. Impaired power quality can lead to reduced system reliability, reduced availability and damage and reduced equipment life.

This study aims to analyze the reliability and certain power quality parameters and provide an overview of the conditions that need to be anticipated on an isolated PV-Diesel hybrid system in order to maintain the reliability and quality of power system.

METHODOLOGY

The research methodology used is literature study method and observation and testing method in the laboratory.

RESEARCH SCOPE

1. The analysis was carried out on a laboratory-scale isolated PV-Diesel hybrid system with a load profile in accordance with the daily household customer 1300 VA expense curve.
2. Power quality standard used is Power Quality Guidelines Electricity Engineers' Association.

3. The power quality parameters evaluated are the relevant parameters that can be detected by the Power Analyzer Fluke 435 and Sunny Webbox.
4. This paper only consists of analysis for night conditions or conditions of pre-generators, generators, and post-generators operate.

LITERATURE REVIEW

A hybrid power system is a system consisting of two or more power sources, operated simultaneously, including (but not necessarily) a storage system and connected to a local distribution network, equipped with a multi-functional inverter to convert DC power and AC, regulates generation and storage, and regulates the voltage and frequency of the system. Small-scale hybrid generating systems are usually called minigrids or micrograms. Local minigrants or micrograms can also be connected to a large grid or national grid, thereby increasing the reliability and power quality of the system[1].

A hybrid power plant system consisting of a renewable energy power plant should be designed in such a way as to the potential conditions and local loads that the system must supply. Due to the unstable nature of renewable energy, influenced by natural conditions and the environment, it is necessary that technology can compensate for the intermittent nature. With a hybrid system, power quality problems from renewable energy sources can be overcome.

To know whether the power quality of a system is good or not, the system need to be tested refers to existing standard. One of the standards governing the power quality is the Power Quality Guidelines standard issued by Electricity Engineers' Association. The standards set by the EEA are as follows [2]:

1. Steady-State Voltage: The test is performed with a data retrieval interval of at least every ten minutes
2. Voltage dips/sags: trigger level is set to 90% of nominal voltage
3. Voltage Swell: trigger level is set 110% of nominal voltage
4. Voltage Harmonics: Testing is successful when 95% of data retrieval done at intervals every ten seconds does not cross the boundary.
5. Frequency: follow the IEC 61000-4-30 standard ie data retrieval at least every ten seconds.

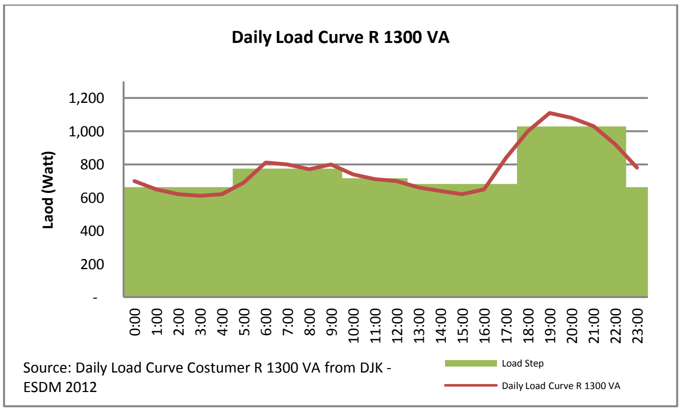

Figure 1. Daily Loads Curve Profile

RESULTS AND ANALYSIS

Performance analyzes are performed on a hybrid system with two power sources that supply home loads but have considerable flexibility for other test scenarios such as on-grid and off-grid. The test is performed with a daily load profile of R-1300 VA that is simulated using a Programmable AC Load Controller.Figure 1shows the load characteristics used during the test.

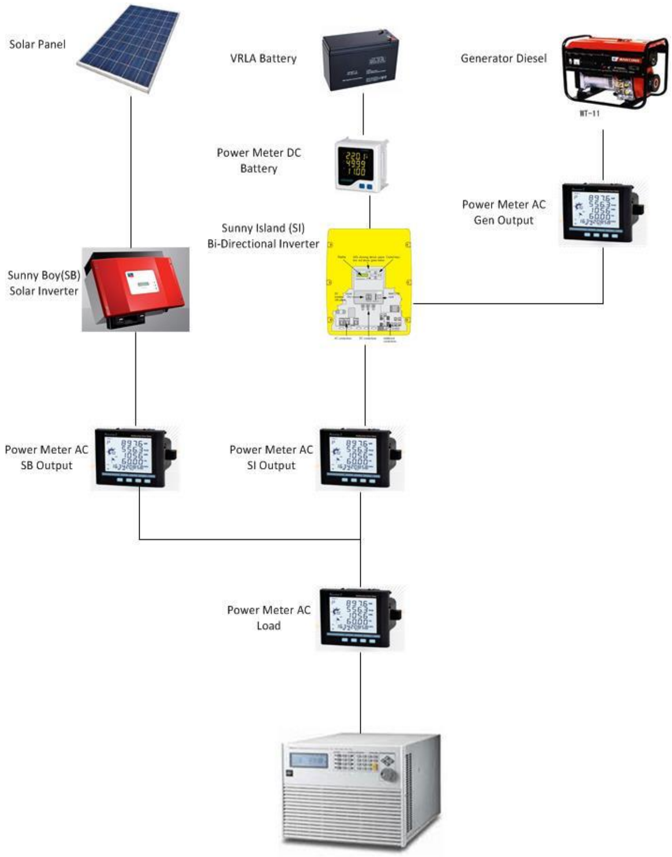

Figure 2. Demonstration Test System Schemes

Schematic in Figure 2is a simple representation of the installed test system. This system has two sources of electricity with one energy storage system. The first power source is a PV array whose output is converted into AC power and maximized with Maximum Power Point Tracker (MPPT) through Sunny Boy as a PV inverter and connected directly to the load and Sunny Island as a bidirectional inverter. This inverter PV output is connected to the bidirectional inverter and the load, so at the time of energy production from the PV array ishighthe PV inverter will supply the load as well as charge the battery. However when the load exceeds the power generated by the PV array then the load will be supplied by the PV arrayand the battery bank through bidirectional inverter. The Bidirectional inverter itself is connected to a single phase power source (grid), a diesel generator, and an energy storage system or battery. In the dark and PV inveter has no power output then the PV inverter will detach from the system and the load will be supplied by the bidirectional inverter with the energy source of the battery. Then when the battery is at the designated and determined State of Charge (SOC) limit then the diesel generator will supply the load and charge the battery through bidirectional inverter[3].

The power quality parameters analyzed in this test are as follows:

1. Steady-State Voltage
2. Voltage Harmonics and Current Harmonics
3. Voltage Dips/Sags
4. Voltage Swell
5. Frequency Deviations

These parameters represent five of the eight power quality parameters found in the Electrical Engineer's Association (EEA) Power Quality Guideline. The power quality parameters analyzed are relevant to the test system working at low voltage levels. The limitations of these power quality parameters are as follows:

1. Steady-State voltage: ± 6% of nominal voltage (216 Volts to 243.8 Volts for nominal voltage 230 Volts).
2. Voltage Dip/Sag: 10% less than nominal voltage for a maximum of one minute (207 Volts for a nominal voltage of 230 Volts).
3. Voltage Swell: 10% more than nominal voltage for a maximum of one minute (253 Volts for a nominal voltage of 230 Volts).
4. Voltage Harmonics: Maximum Voltage Total Harmonics Distortion of 8% for low voltage network.
5. Current Harmonics: Maximum Current Total Harmonics Distortion of 5% for low voltage with current ratio less than 20.
6. Frequency Deviations: ± 1.5% of nominal voltage (49.25 Hz to 50.75 Hz for nominal frequency 50 Hz).

The evaluated parameters are measured in the same place ie Point of Evaluation (POE). POE in this system is load power meter. The load power meter is selected as POE because it is the node closest to the load as can be seen in Figure 2.

The analysis of the five parameters is attempted to be as systematic as possible in order to avoid any phenomenon or problems of missed power quality. Analysis of power quality parameters is done on each situation and time so that we can understand more deeply the factors that cause the occurrence of a phenomenon or problems.

Pre-Generator Analysis is an analysis that is at 19.45 to 21.00. At this time ranges the load is supplied purely by the battery due to deactivated of PVinverter and SOC batteries that have not reached the lower limit to initiate the generator to work. Thus in this analysis we can see the effect of the battery on the power quality parameters tested.

Generator Analysis is an analysis with test time from 21:00 to 00:00. In this analysis the battery that previously supplied the load would pass the SOC lower limit which can initiate the generator until the generator supplies the load and charges the battery. The status of the generator can be observed by looking at Webbox data. So we can analyze the quality parameters tested from the moment the generator starts synchronizing in order to supply power to the system until the system is already running with the generator as the main supply.

Post-Generator Analysis is analysis from 00:00 to 05:45. In the test period of this analysis the batteries and loads previously supplied by the generator will be ordered to stop because the SOC batteries have exceeded their upper limit. The data recorded in this analysis includes the state of the post-stopping system of the generator, this is so that we can analyze whether there is an effect of the current generator running that remains when the generator has stopped working. However, the main highlight of this analysis is the effect of transitions when the generator stops working.

PRE-GENERATORANALYSIS

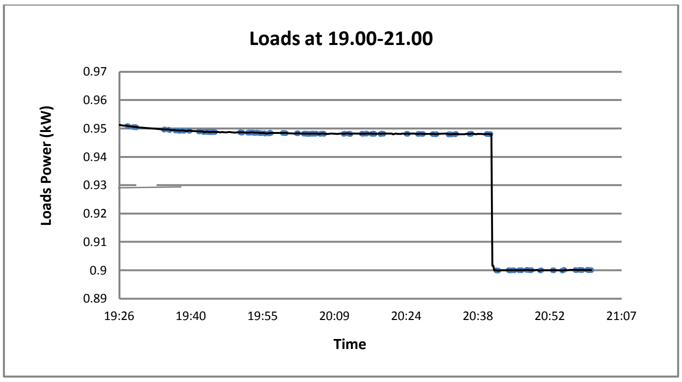

Figure3. Loads at 19.00-21.00

At 19:00 to 21:00 the load is only supplied by the battery while at this time the load is the range where the peak load occurs. The load supplied by the system is worth 960 Watt to 900 Watt. At 20:40 is the time when the load power changes directly from 948 Watt to 900 Watt.

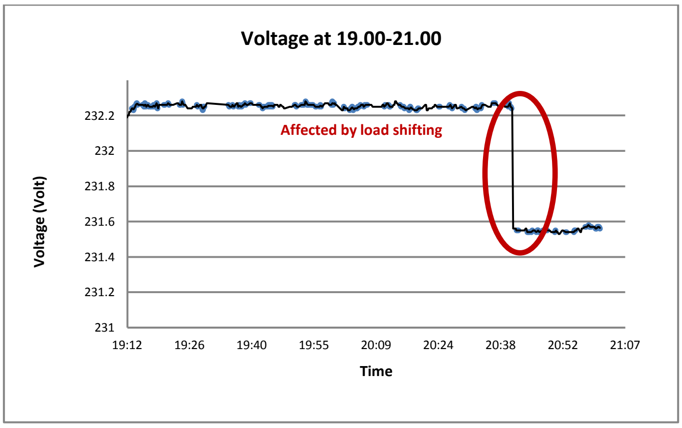

Figure4. Voltages at 19.00-21.00

Steady State Voltage, Voltage Dips/Sags and Swell

Voltage at 19:00 to 21:00 does not exceed the standard limit set. It appears that the magnitude of the voltage changes in proportion and follows the load changes. When the load is still around 950 Watt the measured voltage on the POE is worth 232.25 Volts and when the load turns to 900 Watt the voltage turns to 231.5 Volt.

Voltage Harmonics

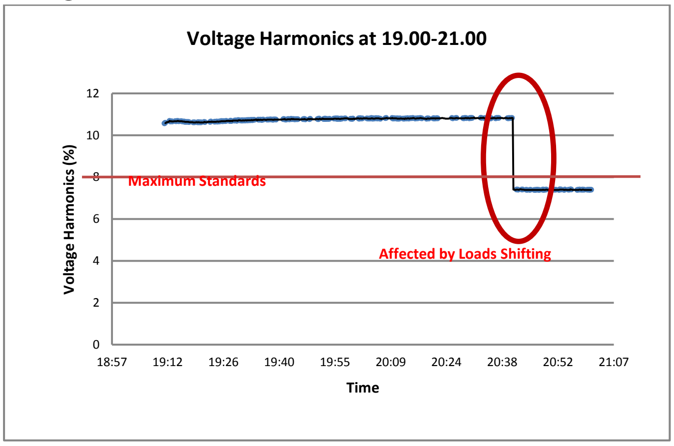

Figure5. Voltage Harmonics at 19.00-21.00

In this analysis the voltage harmonics exceeds the standard limit of 8%. When the load is worth 950 Watt voltage harmonics continue to be beyond the standard of 10.7%. However when the load power drops to 900 Watt voltage harmonics it drops to 7.4%. Voltage is basically influenced by the source of electrical energy. At this time period the source of pure electric energy from the battery through the bidirectional inverter Sunny Island. In the Sunny Island specification it is mentioned that the bidirectional inverter will not issue a voltage harmonic greater than 3%[4].These specifications should be achievable because all input criteria conform to manual specifications except for an unattended environment temperature parameter of 25%. When concluded simply the use of batteries to supply the load causes the harmonic voltage exceeds the limit. However, it is worth noting the comparison between the load power and the voltage harmonics so as to draw the conclusion of the cause of the passing of the voltage harmonic boundary under these conditions need to be more comprehensive and specific test and analysis.

Frequency Deviation

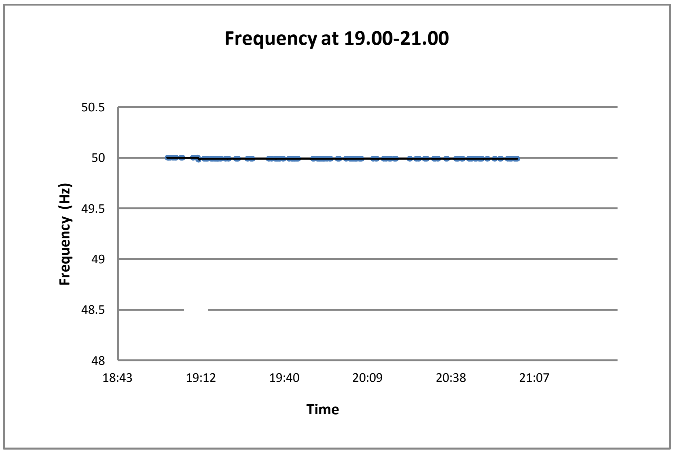

Figure 6. Frequency 19.00-21.00

The use of batteries to supply the loads at 7 pm to 9 pm does not cause frequency issues at all. The measured frequency is very stable with a value of 49.99 Hz.

Current Harmonics

In Pre-Generator testing it can be observed that the load power is inversely proportional to current harmonics. When the load turns down the harmonic current increases just as much as 1.67%. However, it should be understood that in this condition the work is bidirectional inverter while the previous analyzed work is bidirectional inverter and PV inverter. The performance of PV inverters and bidirectional inverters is complementary to others which means that both inverters have an inverse proportion, when the inverter PV output is down the bidirectional output of the inverter will rise as the PV inverter output rises, the bidirectional output of the inverter will decrease. Therefore it can be concluded that the current harmonics are not only influenced by the load but also the inverter components that work on the system. While the harmonic current values in this test remain beyond the limit of reaching 53.24%.

Conclusion of Pre-Generator Analysis

Battery use in Pre-Generator analysis does not reduce system reliability but creates power quality problems. Power quality problems arise in the voltage harmonic parameters where the value reaches 10.7% when the load is 950 Watt. The harmonic current in this analysis also far exceeds the limit up to 53.24%. The cause of the magnitude of harmonic voltage and current harmonics in this analysis can not be determined with existing data and requires more specific testing and analysis.

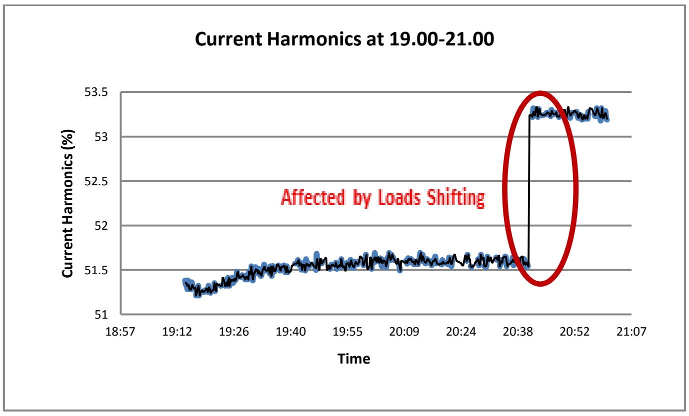

Figure7. Current Harmonics at 19.00-21.00

GENERATORANALYSIS

At the time of this transition when it matches the generator setting starts to light up when the SOC passes the value of 40%, it is present when the generator test can be initiated to light up even though it has not crossed the SOC limit. Data from Webbox in

Table **1**indicates that the generator is initiated to light up when the SOC is 50.22%. But the generator can not directly sync with the system because one of the requirements of parallel generator is not met the same voltage. Another thing that causes the first, second and third sync failures is the load that is supplied is so small that the generator is inefficient and can not start because of under-loading. As a result, the generator failed to sync three times and Sunny Island locked the system to avoid starting again from 22.15 hours to 23.10.

Table 1. WebboxData at night analysis

TimeStamp	BatSoc	BatSocErr	GenRelay	GenStatus
hh:mm	%	%		
21:00	56.78	12.7	1: Off	1: Off
21:05	56.19	12.7	1: Off	1: Off
21:10	55.6	12.71	1: Off	1: Off
21:15	55.01	12.8	1: Off	1: Off
21:20	54.4	12.8	1: Off	1: Off
21:25	53.82	12.8	1: Off	1: Off
21:30	53.22	12.85	1: Off	1: Off
21:35	52.61	12.9	1: Off	1: Off
21:40	52.01	12.9	1: Off	1: Off
21:45	51.42	12.9	1: Off	1: Off
21:50	50.83	13	1: Off	1: Off
21:55	50.22	13	2: On	4: Warm
22:00	49.62	13	1: Off	11: Fail
22:05	49.02	13.04	1: Off	11: Fail
22:10	48.42	13.1	2: On	4: Warm
22:15	48.2	13.1	1: Off	12: FailLock
22:20	48.2	13.1	1: Off	12: FailLock
22:25	48.06	13.18	1: Off	12: FailLock
22:30	47.52	13.2	1: Off	12: FailLock
22:35	46.91	13.2	1: Off	12: FailLock
22:40	46.31	13.22	1: Off	12: FailLock
22:45	45.69	13.3	1: Off	12: FailLock
22:50	45.09	13.3	1: Off	12: FailLock
22:55	44.49	13.3	1: Off	12: FailLock
23:00	43.9	13.36	1: Off	12: FailLock
23:05	43.29	13.4	1: Off	12: FailLock
23:10	42.68	13.4	1: Off	12: FailLock
23:15	42.05	13.4	2: On	6: Run
23:20	42.82	13.5	2: On	6: Run
23:25	45	13.5	2: On	6: Run
23:30	47.08	13.5	2: On	6: Run
23:35	48.85	13.55	2: On	6: Run
23:40	50.53	13.6	2: On	6: Run
23:45	52.2	13.6	2: On	6: Run
23:50	53.86	13.6	2: On	6: Run

The new generator succeeded in syncing and started supplying power to the system at 11:15 pm. This can happen because Sunny Island automatically adjusts the voltage, and by that time the SOC battery is also getting smaller. In this condition the generator works to supply the load and the battery. Thus the generator is no longer in an under-loading state. However when the generator has been running several times observed the current flows from the system to the generator that causes the generator braking.

Another thing to note in this analysis is the transition of load replacement by the testers. The system operates without load from 23.17 to 23.27 because at that time there is a load setting to be used until 00:00. This means that data at 23.17 to 23.27 is not used as a reference in evaluating power quality. It should also be noted that the generator used has a capacity of 6.5 kW while the total load power programmed in this test coupled with the capacity of the battery to be charged is 900 W which causes the synchronous failure of the generator as described earlier. In addition to this test the system uses a voltage of 230 Volt while the generator used has 220 Volt specification. Therefore, in this test will be presented briefly problems that occur when the system uses a voltage of 220 Volts.

Steady State Voltage, Dips/Sags and Swell

According to the EEA the limitation of steady state voltage is approximately 6%. This means that the nominal voltage used in the test system is 230 Volts, the lower limit is 216.2 V and the upper limit is 243.8 V. The lowest steady state voltage recorded on the power meter data at the POE is 222.52 Volts at 23.43 when the load power is 800 Watt and frequency 50.77 Hz. While the highest steady state voltage is 231.6 Volts at 231.6 Volts when load power drops to 786 Watt and 48.02 Hz frequency. This means that steady state voltage does not exceed the power quality standards of the EEA. Likewise with voltage dips/sags and swell that has a minimum voltage limit of 207 Volts and a maximum voltage of 253 Volts.

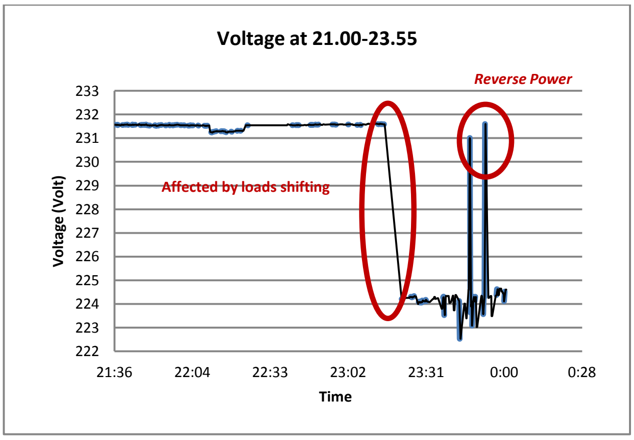

Figure8. Voltage at 21.00-23.55

Voltage drops to 222.52 Volts and is in the range of 224 Volts when the system works due to the nominal voltage of the systemdifference to the nominal voltage of the generator. When a generator with a capacity of 6.5 kW supplies a load which is only 900 Watt then the system is supplied solely by the generator and therefore the system voltage adjusts to the nominal voltage of the generator 220 Volt. It should be noted that although all loads are supplied by the generator, the generator supply still passes Sunny Island therefore Sunny Island keeps synchronizing for the state when the load is more than the power generated by the generator so that the parallel between the generator and Sunny Island with the battery can be done. Because of the lack of nominal voltage used by the generator, there are times when the generator pulls the current from the system (reverse power) and is observed as if it was braking so that it can be seen on the graph at 23:47 and 23.52 measured voltage is the nominal voltage of the system which is about 231 Volt.

Voltage Harmonics

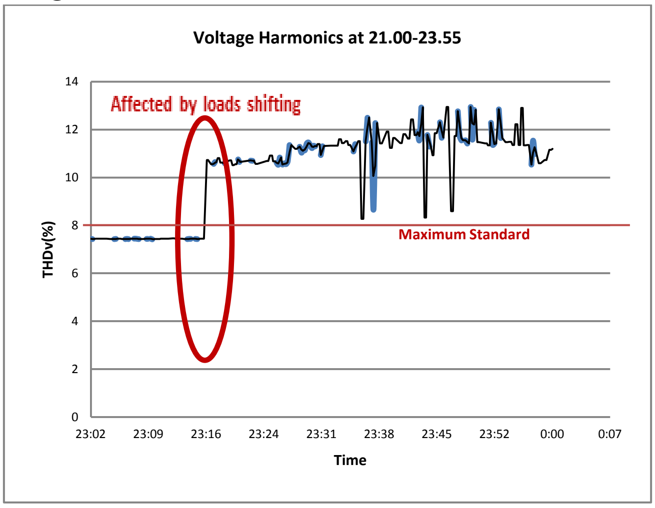

Figure9. Voltage Harmonics at 21.00-23.55

According to EEA the voltagetotal harmonic constraint is 8%. Before the generator operates the voltageharmonic is 7.41% with a 900 Watt load power but its value jumps beyond the standard limit when the generator starts supplying the load. When the smallest voltage harmonic generator has a value of 8.27% and has crossed the limit while the highest value is 12.85%. So it can be concluded that the use of generators with different nominal voltage causes the voltageharmonic to cross the limit. This is certainly because the generator works by using many coils and iron core so that the iron core saturation level used can lead to greater voltage harmonic value. However, it can be noted that the voltage harmonic graph with the voltage parameters when the generator supplies the observed load is inversely proportional so it can not be ascertained whether the use of a generator with the same nominal voltage can cause similar voltage harmonic problems.

Frequency Deviations

The frequency deviation limitations in the EEA are 49.25 Hz to 50.75 Hz. The use of generators in this analysis results in problems with frequency parameters. When the generator works the previously stable working frequency at 49.99 Hz turns to 51.34 Hz and after that fluctuates. The largest frequency value is 51.85 Hz at 23.43 and the lowest is 48.02 Hz at 23:52. Frequencies that work above the maximum limit are the result of generators working on Under-Load conditions where a supply of 6.5 kW is forced to supply a load of only 900 Watt. While the value 48.02 observed along with the increase of voltage to 231 Volt which means at that time the generator draw current from Sunny Island and result as if Sunny Island with 5 kW capacity forced to supply load of 6.5 kW causing condition of Overloading and cause the value of frequency down.

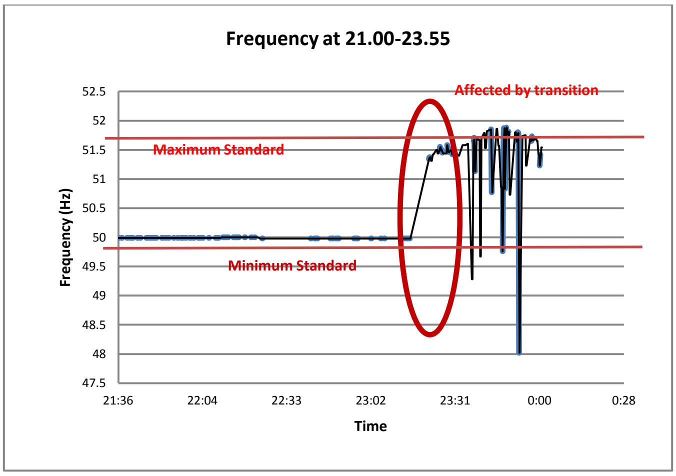

Figure10. Frequency at 21.00-23.55

Current Harmonics

From Figure11can be observed that the active generator effect on the currentharmonic. Before the generatoractive the current harmonic has exceeded the standard limit of 53.15%. After the generator actived harmonic increases more than 2%. This is because the generator also has a non-linear component that adds the current harmonic contribution.

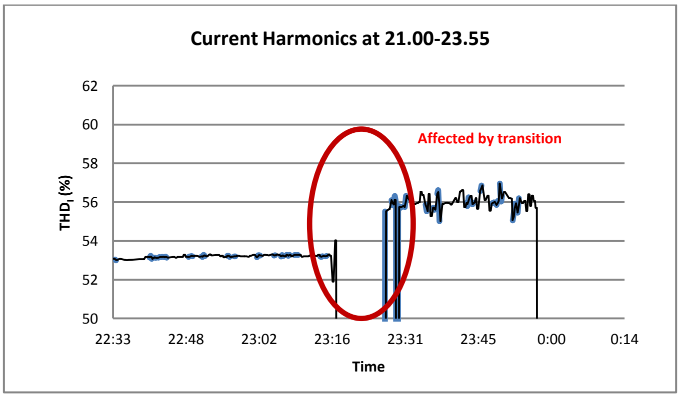

Figure11. Current Harmonics at 21.00-23.55

Generator Test at System Voltage 220 Volt

This test is done by using the system voltage in accordance with the generator voltage specification is 220 Volt and then observed the performance of the system. From Table2it can be observed that the generator on this system can work instantly without any files. Generator is initiated on SOC battery 46.71% and instantly lights up but SOC problems occur ie SOC down from 46.71% to 21.63%. This is a problem because the battery is equipped with 20% SOC protection so that if the SOC below it then the system will disconnect the network, this protection is done so as not to cause damage to the battery. SOC is caused by a starting generator that draws large currents from the system instantaneously. Problems occur in loads that escape even when the generator is on.

At the burden appears Alarm UnderVoltage Protection and also Frequency Error due to starting generator. When the load is tried connected always appear Frequency Error up to five minutes later then the load can be reconnected with the system. At 00:45 loads that have been reconnected to escape from the system due to Frequency Error. In the chroma the frequency constraint so as not to cause alarm frequency is 45 Hz to 440 Hz while Under Voltage Protection occurs when there is a surge of instantaneous or transient currents that cause the voltage drops drastically in a fast time. This indicates the decrease in SOC is due to the current flowing to the generator in large quantities when starting. While the frequency failure is not caused because the generator capacity is overcapacity but because the generator operates occasionally reverse power occurs causing braking and causing the system frequency drops below 45 Hz. These phenomena occur because in this hybrid system there is no frequency regulator so that four parallel generator conditions are not fully met.

Table2. WebboxData of Generator Operation at 220 Volt

Time	GenStatus	BatSoC (%)	Time	GenStatus	BatSoC (%)
0:20	1: Off	48.29	2:15	6: Run	51.69
0:25	1: Off	47.76	2:20	6: Run	52.9
0:30	1: Off	47.23	2:25	6: Run	54.09
0:35	1: Off	46.71	2:30	6: Run	55.23
0:40	6: Run	21.63	2:35	6: Run	56.24
0:45	6: Run	22.36	2:40	6: Run	57.27
0:50	6: Run	24.23	2:45	6: Run	58.25
0:55	6: Run	26	2:50	6: Run	59.15
1:00	6: Run	27.69	2:55	6: Run	59.95
1:05	6: Run	29.4	3:00	6: Run	60.7
1:10	6: Run	31.12	3:05	6: Run	61.35
1:15	6: Run	32.91	3:10	6: Run	61.93
1:20	6: Run	34.86	3:15	6: Run	62.47
1:25	6: Run	36.57	3:20	6: Run	62.98
1:30	6: Run	38.1	3:25	6: Run	63.4
1:35	6: Run	39.69	3:30	6: Run	63.82
1:40	6: Run	41.13	3:35	6: Run	64.18
1:45	6: Run	42.74	3:40	9: Cool	77.17
1:50	6: Run	44.32	3:45	10: Lock	81.33
1:55	6: Run	45.8	3:50	10: Lock	80.88
2:00	6: Run	47.3	3:55	10: Lock	80.45
2:05	6: Run	48.91	4:00	1: Off	80.01
2:10	6: Run	50.38	4:05	1: Off	79.56

Result of Generator Analysis

The use of generator in this test causes the problem of power quality either on frequency or voltage harmonic parameters. Frequency parameters are basically a problem not because of the use of generators but the use of generators whose capacity far exceeds the needs of the load. While the voltage harmonics observed a trend that is inversely proportional to the voltage so it is not necessarily the use of generators can always cause voltage harmonic problems. While in terms of reliability when the generator operates on a 230 Volt system there are not many reliability problems that cause the bursting of loads however the generator can not be relied upon to turn on immediately. When the generator is working on a 220 Volt system there is a down / drop voltage problem and the frequency drops below 45 Hz so that the load is disconnected from the system. This problem arises because of the absence of frequency regulator and also the overcapacity generator.

POST-GENERATORANALYSIS

This analysis focuses on analyzing the transition from the pure power supply from the generator to the pure power supply from the battery. Can be observed at 01:05 SOC battery has reached value 77.99%, value close to 80% where the value is upper limit to send signals to the generator to stop. At 01.10 the signal to disconnect the generator was sent and at 01.15 the generator experienced a cooling phase and ensured that within the next ten minutes there was no re-initiation from Sunny Island to power the generator. In Table3 it can also be observed to decrease the voltage when using the generator and not. At the moment the generator operates the smallest entering current of 13.8 Ampere and when the generator is out of operation the current is stable at 2.7 Ampere. Of course this means even though there is a cooling phase the generator has not been operating since 01:15.

Table3.System Operation at 00.50-02.50

Time	Generator Status	BatSoC(%)	Sunny Island Current (A)
0:50	6: Run	73.81	13.8
0:55	6: Run	75.34	14.63
1:00	6: Run	76.75	15.73
1:05	6: Run	77.99	15.03
1:10	8: Disconnect	79.36	16.31
1:15	9: Cool	79.8	2.7
1:20	10: Lock	79.35	2.7
1:25	10: Lock	78.89	2.7
1:30	10: Lock	78.43	2.7
1:35	1: Off	77.98	2.7
1:40	1: Off	77.53	2.7
1:45	1: Off	77.09	2.7
1:50	1: Off	76.63	2.7
1:55	1: Off	76.18	2.7
2:00	1: Off	75.71	2.7
2:05	1: Off	75.29	2.16
2:10	1: Off	74.93	2.7
2:15	1: Off	74.47	2.7
2:20	1: Off	74.02	2.7
2:25	1: Off	73.58	2.7
2:30	1: Off	73.12	2.7
2:35	1: Off	72.65	2.7
2:40	1: Off	72.21	2.7
2:45	1: Off	71.75	2.7
2:50	1: Off	71.3	2.7

Steady-State Voltage, Dips/Sags and Swell

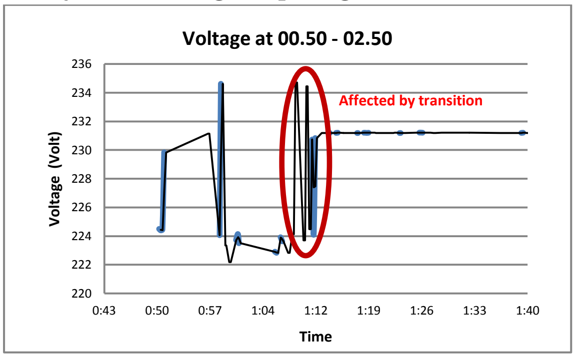

Figure12. Voltage at 00.50-02.50

The measured data shows no significant problems in the transition process from the generator. However, this data shows the value of the voltage when the generator is still operating and visible voltages above 230 Volt more often appear than in the night analysis of the generator. This indicates that more frequent braking on the generator due to the nominal voltage difference in the working components of Sunny Island and Sunny Boy Inverter. When the generator switches into a non-operating system it can still be well supported by the battery so no trips occur. As soon as the load is supplied purely by the battery the voltage back to the nominal voltage of Sunny Island is 230 Volt.

Voltage Harmonics

When the system re-operates using a supply of batteries and without a harmonic voltage generator it looks back well within the voltage harmonic emission limits. When the generator operates the average voltage harmonic value is 11%, passing the harmonic tolerance threshold voltage. However when the generator is not operating, the voltage harmonics continue to be constant value of 4.26%.

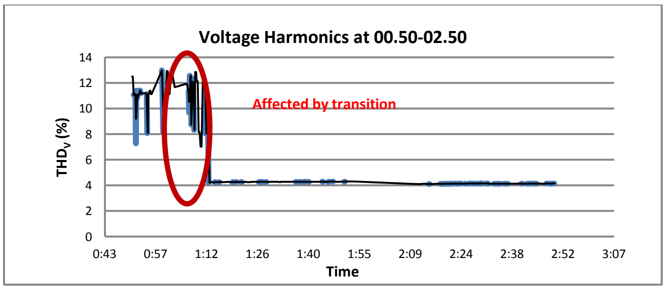

Figure13. Voltage Harmonics at 00.50-02.50

Frequency Deviations

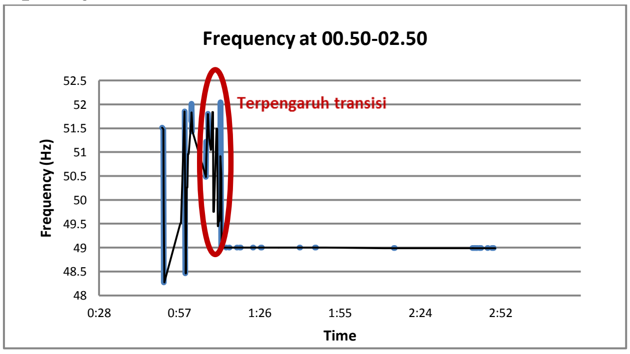

Figure14. Frequency at 00.50-02.50

The EEA boundary to the frequency deviation is 49.25 Hz to 50.75 Hz and from the obtained data there are problems with the frequency deviation. Although the transition from generator to battery does not cause trip system but frequency changed from unstable to stable beyond the limit of 49 Hz. Generally a frequency condition less than its nominal value represents a higher load than its supply capability. However, in this test when the generator has stopped operating, the load power is 700 Watt and the battery is in SOC condition 79.8%. While the power output from Sunny Island is 1000 Watt so the lack of supply power is not the reason for the drop in frequency to 49 Hz and remain at that value. Keep in mind that once the generator stops operating the load is only connected to the battery via Sunny Island. The battery itself obviously has no frequency and therefore does not affect the existence of this frequency deviation but on the other hand Sunny Island is an inverter that produces AC output which has frequency. For that reason there may be a possibility that the inverter is affected by the work of the generator so it can not convert DC power from the battery properly to AC power.

Current Harmonics

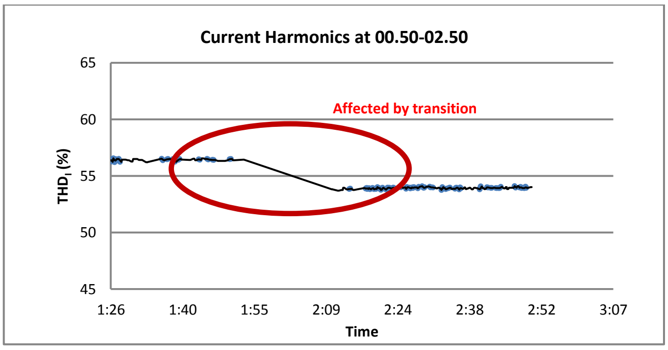

Figure15. Current Harmonics at 00.50-02.50

The observed non-active changes of the generator have a positive effect on the current harmonics. Harmonic current shortly before the non-active generator is 56.33%. After the non-active generator the harmonic current is reduced to 53.82%. Although the positive effect of current harmonic value on this test also exceeded the standard limit.

Conclusions of Post-Generator Analysis

The system transition from the generator to the observed battery poses a problem especially on the frequency parameters. From voltage and harmonic parameters the system voltage works as it is and has even improved compared to the pre-generator night analysis. In contrast to the frequency parameters seen the Sunny Island inverter which generates AC power to the load is affected by the operation of the generator and can not produce AC power with nominal frequency. There is also another problematic parameter is the harmonic current that is worth more than 51%.

CONCLUSSIONS

From the results of research conducted to evaluate the reliability and some parameters of power quality hybrid system isolated in dynamic conditions, it can be concluded several things as follows.

Power quality problems arise in several conditions:

1. The peak load harmonic voltage condition passes the standard.
2. The condition of the system with the harmonic generator supply passes the standard.
3. The post-inactive condition of the bi-directional generator inverter frequency exceeds the standard limit.
4. Supply condition of the generator with the same voltage as the system voltage causes the voltage and frequency to fall over the standard limit.
5. The bidirectional inverter specification indicating the voltage harmonic shall not exceed 3% not achieved.

Reliability issues detected under the following conditions:

1. The 220 Volt generator in a 230 Volt system is not always reliable to work immediately when the battery SOC has reached a predetermined limit.
2. 220 Volt generator in 220 Volt system can work instantaneously after diinisasi but reduce SOC battery drastically causing problems in battery protection.

With such problems it is recommended to perform the following steps:

1. It is recommended to conduct more in-depth testing of post-operation effects of the generator to the power electronics components present in the system.
2. This system requires the regulation of voltage and frequency so that the generator can work well and of course it is advisable to use generators and systems with the same nominal voltage.

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