BRUNEI NATIONAL ENERGY RESEARCH CENTRE

TITLE: Employing Hybrid AC DC for Distribution Power System

NAME: NORHAZRIN BIN MUSA
APPLIED PHYSICS UBD INTERNSHIP
DEPARTMENT OF PHYSICAL AND GEOLOGICAL SCIENCES
DATE: 19th OCTOBER 2015
SUPERVISOR: DR. ARVIND K. S. CHAUDHARY
Table of Contents
1. EXECUTIVE SUMMARY ......................................................................................................................... 2
2. LIST OF ACRONYMS AND ABBREVIATIONS AND ESCALATION OF TERMS .................................... 3
3. OVERVIEW .............................................................................................................................................. 5
4. AIMS ..................................................................................................................................................... 7
5. METHODOLOGY ............................................................................................................................... 7
6. THE ADVANTAGES OF USING HYBRID AC DC ............................................................................... 10
   6.1 Direct current system can save about 50% of money ........................................................................ 10
   6.2 Direct current system is less complex than the Alternating current system ..................................... 12
7. TOTAL HARMONICS DISTORTION AND ITS EFFECT ON ELECTRICAL POWER SYSTEM .......... 14
   7.1 What is Total Harmonics Distortion? ............................................................................................... 14
   7.2 Calculation of Total Harmonics Distortion ...................................................................................... 14
   7.3 Effect of Harmonics Distortion ....................................................................................................... 15
8. CASE STUDY ...................................................................................................................................... 17
   8.1 Is DC’s place in the Home? [8] ....................................................................................................... 17
   8.2 ABB to supply innovative DC power distribution system to green data center [1] .......................... 18
   8.3 Shipping industry soon to get its hybrid vessels ............................................................................. 20
   8.4 MVDC Distribution System in Japan [10] ........................................................................................ 21
9. CONCLUSION .................................................................................................................................... 22
10. REFERENCES ...................................................................................................................................... 23
11. APPENDIX ....................................................................................................................................... 24
    11.1 APPENDIX A : EFFICIENCY OF EXTERNAL POWER SUPPLIES ........................................... 24
1. EXECUTIVE SUMMARY

The increasing number of devices using direct current nowadays create a dilemma for engineers in Brunei whether we should continue to rely on alternating current or not. This problem is of interest because most of these devices use direct current which currently can be obtained through conversion of alternating current and another method is by using a solar panel which in Brunei there is only a few of people can affordable using it. Currently Brunei is being supplied with a alternating current which is being distributed to be used by end user. Although currently Brunei power electric system can support the use of direct current through conversion of alternating current there is a drawback such as power losses during the conversion and this matter should not be ignored because every small losses in appliances can make efficiency of power system decrease. Back in September 2014, His Majesty Sultan Haji Hassanal Bolkiah emphasized that Brunei is to reduce power consumption of about 63 percent in total energy consumption by 2035 as in Brunei Vision 2035 aims to make Brunei well recognized for its good quality of life which is sustainable.

This report will focus on a hybrid AC DC efficiency. The report also will discuss about why we should use Hybrid AC/DC in our distribution system. This includes the usage of DC based appliances how the devices derived the idea of using direct current, application of distributed generation producing dc power. DC distribution systems use less copper and are more efficient.
2. LIST OF ACRONYMS AND ABBREVIATIONS AND ESCALATION OF TERMS

AC  Alternating current (AC) is an electric current which the flow of electric charge periodically reverses direction.

DC  Direct current (DC) is an electric current which the flow of electric charge is only in one direction.

AC-DC  Alternating current to Direct current (AC-DC) is a conversion of AC to DC.

DC-AC  Direct current to Alternating current (DC-AC) is a conversion of DC to AC.

GWh  Gigawatt hour is a unit of energy equal to $10^9$ watts hours.

kW  Kilowatts (kW) is a unit of energy equal to 1000 watts.

ACS  Automation of Complex Power System (ACS) is an institute in which their focus of research are on Grid operations and ICT for Energy.
Microgrid

Microgrid is a localized grouping of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized grid (macrogrid).

PV

Photovoltaics (PV) is a process where solar energy is converted to direct current using a semiconducting material.

Transformers

Transformers is an electric device that are used to increase or decrease the voltages of alternating current in electric power application.

UTRC

United Technologies Research Centre (UTRC) is the central research and development organization of United Technologies, which have 50 diversified company in which one of the company products is air conditioner.
3. OVERVIEW

Hybrid AC/DC is the integration or the adding process of DC power technologies into the existing AC systems. And it is being display that the true capabilities of direct current power system is yet to be discovered as it could be better than the alternating current power system. That is why Hybrid AC DC is one of the step where engineers around the world trying to apply it towards the present AC system to see whether it can be productive or not.

From the power generation view at present there are many distributed energy resources, such as photovoltaic systems, which can generate power in DC form. Many of the modern electrical loads and also energy storage systems are working internally with DC or work equally well with DC power and connect to the AC systems through converters. Thus, application of DC power would decrease of many AC-DC and DC-AC conversion stages, which would in turn result in considerable decrease in component costs and power losses, and increase in reliability. Also, many power quality issues, such as harmonics and unbalances, are not present in DC systems.

In spite of all these advantages, however, there are a number of factors besides the entity of legacy systems, which hinder the adoption of DC systems. One of the main reasons is that until very recently, there has been almost no standardization for DC systems, particularly at low voltage level. Relatively little industrial experience, safety and protection concerns, and the mental barrier against a paradigm shift are some other factors slowing down the wide-spread use of DC systems. However, the DC technology has already started to be integrated into the existing AC system step by step. This is leading to the emergence of hybrid AC/DC systems in which AC and DC buses are
connected through interlinking, bidirectional converters. Control of the interlinking converter, as the energy bridge between the AC and DC sides, is a critical issue for ensuring stability and utilizing the system potential to improve the quality of service. Microgrids, which are characterized by a combination of dispersed generation units, storage systems and loads, are one key application where hybrid AC/DC systems may offer significant benefits.

ACS institute also have done a research where their main focus of the research is on the quantification of energy efficiency improvement that hybrid AC/DC systems may introduce in buildings, as well as on the control of the interlinking converter, with the aim of improving the stability and power quality of Microgrids. In particular, they are working on the improvement of the techniques for load sharing among the resources connected to AC and DC buses of the system. In addition, they aim to control the interlinking converter in a way that the voltage harmonic distortion at the AC bus, resulting from the non-linear load and the voltage unbalances, are mitigated. The research is supported by funding by United Technologies Research Center (UTRC).
4. AIMS

The aims of this report is to report the advantages of using Hybrid AC/DC and how it can help to improve power system efficiency for Brunei Darussalam.

5. METHODOLOGY

Below are the examples of the idea that could lead the use of Hybrid AC/DC supply in distribution network:

1. In the Modern Era of electronic most of the home appliances are operated using DC power. For Example Lighting is widely considered to account for around 20% of global electricity consumption, and in 2012 report from the International Energy Agency estimates that up to 15% of domestic energy is consumed through ‘gadgets’ - i.e. computers and mobile phones.

Figure 1 shows an example of devices using direct current (retrieved September 21, 2015 from https://thumbs.dreamstime.com/z/laptop-mobile-phone-digital-tablet-pc-21364315.jpg)
2. Application of distributed generation principle to improve reliability and efficiency of energy supply by generating power with renewable energy sources (wind generator, PV solar unit, fuel cell) which may supply the consumers with DC power.

3. Output power of renewable sources sometimes is not consistent so there are energy storage devices. So if the output power is not sufficient therefore there is always a reserve of dc current energy.

Figure 2 an example of renewable energy sources that can supply DC power (retrieved September 21, 2015 from https://www.totalenergycompany.com/pdf/MansoorFortenbery.pdf)

Figure 3 shows that there is a DC energy storage for the production of energy (retrieved September 18, 2015 from https://www.apec-conf.org/wp-content/uploads/IS1-4-5.pdf)
4. Using efficient converters and newest power electronics DC power may be easily and effectively converted to the ac power at different voltage level and necessity of transformers will be decreasing.

Figure 4 shows the 3.3 kW single phase PFC rectifier system (retrieved September 21, 2015 from https://www.pes.ee.ethz.ch/uploads/tx_ethpublications/HighPerformanceRectifierSystem_ElektronikPraxis_English_1_.pdf)

5. Another reason is that direct current power can be sustained at high amount which is the energy can be stored at large amount depends on the types of the container. Such floating energy storage can even power the power grid.

<table>
<thead>
<tr>
<th>Types of ship</th>
<th>Power(GW)</th>
<th>Power(kW)</th>
<th>energy(GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container ship</td>
<td>1.0-2.0</td>
<td>2000000</td>
<td>2.0-4.0</td>
</tr>
<tr>
<td>Barge ship</td>
<td>0.2-0.5</td>
<td>500000</td>
<td>0.2-0.5</td>
</tr>
<tr>
<td>Tanker</td>
<td>0.2-0.5</td>
<td>500000</td>
<td>0.8-2.0</td>
</tr>
<tr>
<td>Ferry</td>
<td>0.5-1.0</td>
<td>1000000</td>
<td>1.0-2.0</td>
</tr>
</tbody>
</table>

Table 1 shows the amount of energy the container can stored for different types of ship (retrieved September 21, 2015 from https://blogs.dnvgl.com/utilityofthefuture/floating-energy-storage-for-grid-and-maritime-applications)
6. THE ADVANTAGES OF USING HYBRID AC DC

Below show the advantages of using hybrid ac-dc in distribution system:

6.1 Direct current system can save about 50% of money
Since nowadays many of the appliances that can be found inside one household are mainly DC based therefore we can expect that inside one household there are huge amount of power losses due to conversion of AC to DC. The problem is that the converter use for AC and DC conversion is different in price though the converters are of the same type. Figures below show the price of AC and DC converter for each type of converter:

<table>
<thead>
<tr>
<th>Converters</th>
<th>Voltage</th>
<th>Hardware</th>
<th>Assumptions</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC/AC PWM 40 kVA</td>
<td>400 Vdc / 400 Vac</td>
<td>Battery &amp; Off-grid Inverter</td>
<td>$1.60/Watt (Inverter)</td>
<td>$64,000</td>
</tr>
<tr>
<td>DC/AC PWM 20 kVA</td>
<td>1000 Vac/500 Vdc</td>
<td>Wind Turbine Rectifier</td>
<td>Use two (2) 15 kw modules and one Frame/Rectifier from Starline Enterprises</td>
<td>$26,000</td>
</tr>
<tr>
<td>DC/AC PWM 10 kVA</td>
<td>500 Vdc/400 Vac</td>
<td>Wind Turbine Inverter</td>
<td>$0.40/Watt (Inverter) installed</td>
<td>$8,000</td>
</tr>
<tr>
<td>DC/AC PWM 3 kVA</td>
<td>400 Vdc/400 Vac</td>
<td>PV Inverter</td>
<td>$0.40/Watt (Inverter)</td>
<td>$4,000</td>
</tr>
<tr>
<td>DC/AC PWM 40 kVA</td>
<td>400 Vdc/400 Vac</td>
<td>Fuel Cell Inverter</td>
<td>$0.40/Watt (Inverter)</td>
<td>$4,000</td>
</tr>
<tr>
<td>DC/AC PWM 40 kVA</td>
<td>400 Vdc/400 Vac</td>
<td>PV Inverter</td>
<td>$0.46/Watt (Inverter)</td>
<td>$1,380</td>
</tr>
<tr>
<td>AC/DC PWM 40 kVA</td>
<td>1000 Vac/500 Vdc</td>
<td>Microturbine Inverter</td>
<td>Use three (3) 15 kw modules and one Frame/Rectifier from Starline Enterprises</td>
<td>$29,000</td>
</tr>
</tbody>
</table>

**Total** $152,380

Figure 5 shows the cost of converter equipment for AC system [6]
<table>
<thead>
<tr>
<th>Converters</th>
<th>Voltage</th>
<th>Hardware</th>
<th>Assumptions</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/DC 100 kVA</td>
<td>20 kV/400 Vdc</td>
<td>Rectifier</td>
<td>Use seven (7) 15 kw modules and one Frame/Rectifier from Starline Enterprises</td>
<td>41,000</td>
</tr>
<tr>
<td>DC/DC 40 kVA</td>
<td>400 Vdc / 380 Vdc</td>
<td>Battery Converter</td>
<td></td>
<td>$4,886</td>
</tr>
<tr>
<td>AC/DC PWM 20 kVA</td>
<td>500 Vdc/400 Vac</td>
<td>Wind Turbine Rectifier</td>
<td>Use two (2) 15 kw modules and one Frame/Rectifier from Starline Enterprises</td>
<td>$26,000</td>
</tr>
<tr>
<td>DC/DC 10 kW</td>
<td>400 Vdc / 380 Vdc</td>
<td>PV inverter</td>
<td>Alpha System 14kW, 380V to 48V; 19/23&quot; universal mount system - From Pricing Sheet Attached - Extrapolated Using $349/kW of Capacity</td>
<td>$3,490</td>
</tr>
<tr>
<td>DC/DC 10 kVA</td>
<td>400 Vdc / 400 Vdc</td>
<td>Fuel Cell inverter</td>
<td>Alpha System 14kW, 380V to 48V; 19/23&quot; universal mount system - From Pricing Sheet Attached - Extrapolated Using $349/kW of Capacity</td>
<td>$3,490</td>
</tr>
</tbody>
</table>
Figure 6 shows the cost of converter equipment for DC system[6]

<table>
<thead>
<tr>
<th>DC/DC 3 kVA</th>
<th>400 Vdc / 400 Vac</th>
<th>DC-DC Converter</th>
<th>Alpha System 14kW, 380V to 48V; 19/23&quot; universal mount system - From Pricing Sheet Attached - Extrapolated Using $349/kW of Capacity</th>
<th>$1,047</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/DC PWM 40 kVA</td>
<td>1000 Vac/500 Vdc</td>
<td>Microturbine</td>
<td>Use three (3) 15 kw modules and one Frame/Rectifier from Starline Enterprises</td>
<td>$29,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$82,913</strong></td>
</tr>
</tbody>
</table>

As shown by the two figure DC does benefits to us as by using DC we can save of total $69,467 (152,380 – 82,913). This is 54% (82,913 divide by 152,380) less cost than in comparison with AC converters.

6.2 Direct current system is less complex than the Alternating current system
Simplicity of distributing power to households for direct current can be shown when a lot of renewable resources easily being installed for example solar panel on rooftop of U.S household. In 2006, some 30,000 U.S. homes had rooftop solar systems. By 2013, that number had grown over to almost 400,000 homes.
Figure 7 shows households in U.S with solar panel on rooftop (retrieved September 21, 2015 from https://gigaom.com/wp-content/uploads/sites/1/2013/10/rooftops-with-solar-cropped.jpg?quality=80&strip=all)

Figure 8 shows the complexity involve in distributing power in alternating current system (retrieved September 21, 2015 from https://http://www.bravoprojects.co.in/images/grid.jpg)
7. TOTAL HARMONICS DISTORTION AND ITS EFFECT ON ELECTRICAL POWER SYSTEM

7.1 What is Total Harmonics Distortion?
The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is used to characterize the linearity of audio systems and the power quality of electric power systems. In audio systems, lower distortion means the components in a loudspeaker, amplifier or microphone or other equipment produce a more accurate reproduction of an audio recording. In radio communications, lower THD means pure signal emission without causing interferences to other electronic devices. Moreover, the problem of distorted and not eco-friendly radio emissions appear to be also very important in the context of spectrum sharing and spectrum sensing. In power systems, lower THD means reduction in peak currents, heating, emissions, and core loss in motors.

7.2 Calculation of Total Harmonics Distortion
For a signal y the THD is defined by the equation:

\[
\text{THD} = \frac{\sum_{h=2}^{\infty} y^2 h}{y_1} \quad \text{(Equation 1)}
\]
According to the standard IEC 61000-2-2, h can be generally be limited to 50. Equation 1 gives a single value indicating the distortion of a voltage or a current flowing at a given point in a distribution system. Harmonic distortion is generally expressed as percentage For current harmonics Equation 1 becomes:

$$THD = \frac{\sum_{h=2}^{\infty} I^2 h}{I_1}$$

While for Voltage Harmonics Equation 1 becomes:

$$THD = \frac{\sum_{h=2}^{\infty} U^2 h}{U_1}$$

7.3 Effect of Harmonics Distortion
The power quality of distribution systems has a drastic effect on power regulation and consumption. Power sources act as non-linear loads, drawing a distorted waveform that contains harmonics. These harmonics can interrupt telephone transmission and degradation of conductors, insulating material in motor sand transformers. Therefore it is better to analyse the effect of these harmonics. The addition of all harmonics in a system is called total harmonic distortion (THD).

Waveform of practical inverters are non-sinusoidal and contain certain harmonics. For low- and medium power application, square wave or quasi-square wave form voltage may be acceptable but for high-power application sinusoidal waveform with low distortion are required. Harmonics content present in the output of a dc to ac inverter
can be eliminated either by using a filter circuit or by employing pulse width modulation (PWM) techniques. Use of filter has the disadvantage of large size and cost, whereas use of PWM techniques reduces the filter requirement to a minimum or to zero depending on the type of application. Traditional two level high frequency PWM inverter have some drawback, such as production of common mode voltage. Multilevel inverter have found better counter to the conventional two–level pulse width modulation inverter to overcome the above problems. In addition they offer the advantage of less switching stress on each device for high voltage high power application, with reduced harmonics content at low switching frequency.

Electric motors experience losses due to hysteresis and losses due to eddy currents set up in the iron core of the motor. These are proportional to the frequency of the current. Since the harmonics are at higher frequencies, they produce higher core losses in a motor than the power frequency would. This results in increased heating of the motor core, which (if excessive) can shorten the life of the motor. The 5th harmonic causes a CEMF (counter electromotive force) in large motors which acts in the opposite direction of rotation. The CEMF is not large enough to counteract the rotation; however it does play a small role in the resulting rotating speed of the motor.
8. CASE STUDY

8.1 Is DC’s place in the Home? [8]
By 2013, a group of IEEE members inspected some of household to get a snapshot of appliances, the list of categories expanded to over 50 small appliances and consumer electronics devices. The devices are primarily run on DC power. Despite with improvements in power supplies, many of the devices have a conversion efficiency of no greater than 80 percent and some low-end devices have efficiencies as low as 65 percent in converting power. Such devices now account for between 15 and 30 percent of a residence’s consumption. In 2012 an average U.S. home consumed 11,252 Kilowatt-hours (kWh). And average home used 20 percent of electricity for the devices which in total is 2,250 kWh consumed by each residence. With an average efficiency of power conversion of 75 percent, that means 562 kWh were lost in power conversion in an average home. On the production side of the equation, residential photovoltaic systems are coming into wider use, producing DC power that also involves significant losses. The smallest PV system typically installed has a capacity of about 1 kilowatt (KW) and produces 5250 kWh annually. According to the National Renewable Energy Lab’s (NREL) PVWatts tool, the losses associated with converting DC to AC in a typical system come to 23 percent, or 241 kWh. The average size installed is 5 kW, so the annual conversion loss amounts to 1,200 kWh for the average system. Then there are electric vehicles, a third major DC element. According to GM, the Chevy Volt needs to have 10.4 kWh fed into the battery for a full charge because of losses and battery conditioning, doing that actually requires 12.9 kWh of electricity. Assuming the Volt is driven the 35-miles-a-day national average, which is roughly the number of miles the
car gets per charge, it will consume 4,700 kWh of electricity per year, of which 912 kWh is lost in conversion and charging the batteries.

So, the current usage of ac continues, more renewables, increase in electric vehicles, and more dc based electronics will be installed, leading to growing conversion losses. Today, a US home with photovoltaic and electric vehicles have a conversion losses of 2,674 kWh annually on a consumption of 15,952 kWh, or 16 percent. This means that more electricity is lost inside the house rather than in delivering that home’s power through the distribution and transmission grids.

### 8.2 ABB to supply innovative DC power distribution system to green data center [1]

The new direct current (DC) system in Switzerland will provide maximum energy efficiency and minimum environmental impact for the green data center facility. On 13th July 2011 ABB the leading power and automation technology group designed and installed direct current (DC) power distribution system for green.ch, one of the top information and communications technology (ITC) service providers in Switzerland. DC technology reduces power conversion losses and the energy efficiency is about 10 to 20 percent more efficient than traditional alternating current (AC) technology for electrical distribution in data centers. DC systems are also less complex and require less space, reducing equipment, installation and maintenance costs resulting in a saving on total facility costs of up to 30 percent. ABB also installed a fully redundant 1 megawatt DC power distribution solution for the 1,500 m² expansion of the existing 3,300 m² data center. It will be designed and engineered to green.ch’s stringent ecological standards.
by Validus DC Systems, an ABB company. The regulations includes a service level agreement, and the expansion began its commercial operation in the first quarter of 2012. In north-central of Switzerland, the green data center supplies customers with secure storage and data management capabilities. The green.ch data center has been selected as ABB’s demonstration site for its new DC technology. It will be used as a showcase for international data center customers seeking to profit from this groundbreaking technology by reaching new benchmarks in energy efficiency for data center technologies. Tarak Mehta head of ABB’s Low Voltage Products division stated that the DC system increases efficiency of the electrical infrastructure and efficiency in the IT room, because less cooling is required as well in the data center itself. Therefore power losses will be reduced and DC is an ideal solution for data centers as it minimizes footprint, installation and maintenance costs, without sacrificing reliability.

Franz Gruter the CEO of green.ch said that their goal is to utilize the most reliable and cost-effective technology while supplying global data center services at the highest standards of output, security and environmental stewardship. The new DC technology of ABB allows them to fulfill our environmental responsibilities as part of our long-term goals. The project underlines ABB’s goal to expand DC power applications. In May 2011, ABB gained a controlling interest in DC system of Validus a leading provider of DC power infrastructure equipment. In 2010, ABB invested to a developer of power management and optimization software for data centers which is Power Assure.
8.3 Shipping industry soon to get its hybrid vessels
Ships equipped with hybrid main propulsion gear is said to be on the market within a year and ABB has been testing the apparatus in a hybrid laboratory in collaboration with Norwegian University of Science and Technology and the Norwegian Marine Technology Research Institute. ABB company said it expects to sign its first contract in the course of the year. Borre Gundersen R&D manager for ABB’s marine activities in Norway explained that Hybrid propulsion systems significantly reduce both fuel consumption and emissions. The aim is to come up with improved solutions for energy-efficient propulsion systems for boats. The results from the researchers’ findings have shown that a direct-current power system that has a battery fitted would reduce 10 – 15 per cent fuel consumption and give less emission than a traditional alternating current system. It is because the stored energy optimises operation of the internal combustion engine, which reduces fuel consumption, emissions of greenhouse gases and particles, and improved power system reliability. The battery is able to absorb peak loads, while the internal combustion engine can continue to operate at its optimal level.

ABB is hopeful that the market for electric and hybrid vessels would expand, with battery capacity expected to double by 2020. In early 2015 engineers were experimenting with alternative fuels to make freight greener. A wind-driven hybrid device known as Vindskip which was designed by a Norwegian engineer in a bid to cut fuel costs and assist shipping companies according to emission guidelines. With almost 90 per cent of all goods being shipped internationally, the International Maritime Organisation (IMO) aims to reduce the environmental impact of ocean liners.
8.4 MVDC Distribution System in Japan [10]
Mitsubishi Electric Corporation announced their plans to build a development and demonstration facility for middle-voltage direct current (MVDC) distribution at its Power Distribution System Center in Marugame, Japan in which expected to be operated in April 2016. MVDC distribution reduces electricity loss during the distribution, making the technologies become well known for business while mitigate environmental impact. MVDC distribution involve environmentally conscious distribution systems that use combine renewable energy such as solar and wind with an electrical accumulator are growing in popularity. The systems generate DC electricity which later converted to AC for general use. However, communication and digital devices in general have to convert it back to DC. The conversion of electricity between AC and DC causes energy loss. MVDC distribution plays an important role in eliminating the DC conversion issue and reduces energy loss, thus reducing facilities costs by using thinner power cables or transmitting electric power longer distances. This induced a reevaluation of DC technology, and Mitsubishi Electric aims to meet the needs of this new DC ecosystem by powering their existing DC technologies such as their distribution board for data center energy conservation and their high speed circuit for railway lines. The company, at the same time, will use this new facility to develop better MVDC for future generation technologies and communicate their value to consumers.
9. CONCLUSION

At present in Brunei most of the power grid are AC system in which there are losses during the conversion from AC to DC. In the future more both DC generation (PV) and DC based appliances will be created or integrated into our way of life. Therefore factors such as energy efficiency, power losses and how much energy must be generated tend to be change, so we must take a consideration how DC can be our alternative way of generating and saving energy for next generation.
10. REFERENCES

2. http://www.acs.eonerc.rwth-aachen.de/cms/E_ON_ERC_ACS/Forschung/Abgeschlossene_Projekte/~euwe/HYBIRD_AC_DC_MICROGRIDS_A_BRIDGE_TO_FUT/lidx/1/
7. https://www.cui.com/efficiencystandards
11. APPENDIX

11.1 APPENDIX A : EFFICIENCY OF EXTERNAL POWER SUPPLIES

RECENT RESEARCH ON HYBRID AC DC

Freiburg/Germany – German Energy storage systems manufacturer ASD Automatic Storage Device is set to exhibit its updated hybrid battery, which has recently in process, at Intersolar 2015. It is distinguished by its extreme durability, which has been made by a specially developed software with an integrated feature that compensates for degradation.

Wolfram Walter, founder of ASD and inventor of the ASD solar storage system said that the new electronic storage control system extend the storage solution’s lifetime even further and the method of compensating for degradation make the cells age at slow pace than those produced by other storage systems manufacturers. In addition, the components of the storage from brands such as Siemens and Studer also contribute towards making the hybrid battery even more durable.

The field test for the updated battery, which is based on lithium-iron-phosphate technology, was completed in the early 2015. During the beta period, all power classes were successfully tested in selected households for a duration not less than six months. Since then, the battery has been fully use in production at ASD’s factory in Umkirch near Freiburg, Germany. In addition to enhancing the battery’s control system, ASD has made the device easier to be installed in which the number of cables connected have been reduced from four to just two.

The hybrid battery runs for both AC and DC coupling in which it enables more flexible planning than other storage types that are specifically designed for either AC or DC power system. Most of the storage systems on the market are only configured for AC operation. In cases such as power cut, the hybrid battery can supply the house with electricity until they are battery run out of energy. Power system that run on DC operation can always be recharged and provide a constant supply of electricity to all the household devices. The hybrid battery combines the advantages of both modes but at a customer’s request can be produced for exclusive AC or DC operation.

The new storage system is available in four sizes ranging from 5 to 13 kilowatt hours (kWh). On request, it can be installed to provide the house with emergency back-up power on all three phases in addition to its normal operating mode. In the event of a power cut, all the devices in the building are supplied with power instead of a select few.
INTERNATIONAL EFFICIENCY MARKING PROTOCOL

The international efficiency marking protocol is a system where products manufacturer can label the minimum efficiency performance of an external power supply, so that the manufacture and government can easily identify the unit’s efficiency. The mark’s purpose is not for the consumer to know but rather it display the performance of the external power supply.

HISTORY OF ENERGY EFFICIENCY REGULATION

In the early 90’s, it is said that there were more than one billion external power supplies active in the United States. The efficiency of these power supplies, mainly utilizing linear technology, could be as low as 50% and still draw power when the application was turned off or not even connected to the power supply (referred to as “no-load” condition). Experts calculated that without efforts to increase efficiencies and reduce “no-load” power consumption, external power supplies would account for around 30% of total energy consumption in less than 20 years. As early as 1992, the US Environmental Protection Agency started a voluntary program to promote energy efficiency and reduce pollution which eventually became the Energy Star program. However, it was not until 2004 that the first mandatory regulation dictating efficiency and no-load power draw minimums was put in place.
Figure 1 below shows that after year 2004 some countries and regions started to make stricter regulations and move from voluntary to mandatory programs.

Figure 1 the image above traces the path from CEC’s 2004 regulation up to the new Level VI standard set to take effect February 2016 [1]
Some of the countries that already implemented their mandatory regulation on energy efficiency and no-load power are United States, Canada and European Union. Figure 2 below shows the efficiency energy level for the three countries:

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>COUNTRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>United States</td>
</tr>
<tr>
<td>IV</td>
<td>Canada</td>
</tr>
<tr>
<td>V</td>
<td>European Union</td>
</tr>
</tbody>
</table>

Figure 2 shows the efficiency energy level regulation for three different countries[2]

The International Efficiency Mark specifies the level of minimum energy efficiency and no-load efficiency level and the mark is being displayed on the devices nameplate which usually can be found at the back of the devices.

An example of a device with the International Efficiency Mark is shown below:

Figure 3 shows an example of the mark certified by the international efficiency marking protocol[4]
Figures below show the criteria of energy efficiency level for each mark:

<table>
<thead>
<tr>
<th>Mark</th>
<th>Performance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Used if none of the other criteria are met.</td>
</tr>
<tr>
<td>II</td>
<td>0 to ≤ 10 watts ≤ 0.75 0 to &lt; 1 watt ≥ 0.39 x P_no</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 to 250 watts ≤ 1.0 1 to &lt; 49 watts ≥ 0.107 x ln(P_no) + 0.39</td>
</tr>
<tr>
<td></td>
<td>&gt; 49 watts ≥ 0.82</td>
</tr>
<tr>
<td>III</td>
<td>0 to &lt; 10 watts ≤ 0.5 0 to &lt; 1 watt ≥ 0.49 x P_no</td>
</tr>
<tr>
<td></td>
<td>10 to 250 watts ≤ 0.75 1 to &lt; 49 watts ≥ 0.09 x ln(P_no) + 0.49</td>
</tr>
<tr>
<td></td>
<td>&gt; 49 watts ≥ 0.84</td>
</tr>
<tr>
<td>IV</td>
<td>0 to 250 watts ≤ 0.5 1 to &lt; 1 watt ≥ 0.5 x P_no</td>
</tr>
<tr>
<td></td>
<td>&gt; 49 watts ≥ 0.85</td>
</tr>
<tr>
<td>V</td>
<td>0 to &lt; 50 watts ≤ 0.5 for ac-ac; ≤ 0.3 for ac-dc 0 to ≤ 1 watt Standard: ≥ 0.480 x P_no + 0.140 Low Voltage: ≥ 0.497 x P_no + 0.067</td>
</tr>
<tr>
<td></td>
<td>≥ 50 to ≤ 250 watts ≤ 0.5 1 to &lt; 49 watts Standard: ≥ 0.0626 x ln(P_no) + 0.622 Low Voltage: ≥ 0.0760 x ln(P_no) + 0.561</td>
</tr>
<tr>
<td></td>
<td>&gt; 49 to 250 watts</td>
</tr>
</tbody>
</table>

Note: 1 P_no is the nameplate output power of the unit under test. 2 AC-AC external power supplies are not required to meet the no-load mode power requirement. 3 ln refers to natural log. 4 A low-voltage model is an EPS with nameplate output voltage of less than 6 volts and nameplate output current greater than or equal to 550 milli amperes. A basic-voltage model is an EPS that is not a low-voltage model.

Figure 4 shows the criteria for energy efficiency level I to V (retrieved September 02, 2015 from https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/International_Efficiency_Marking_Protocol.pdf)

Figure 5 shows the criteria for Single Voltage External Power Supply of energy efficiency level VI (Retrieved September 09, 2015 from https://www.cui.com/efficiencystandards)
Figure 6 shows the criteria for Multiple Voltage External Power Supply of energy efficiency level VI (Retrieved September 09, 2015 from https://www.cui.com/efficiencystandards)

The table below explains the meaning of each mark:

<table>
<thead>
<tr>
<th>Sample Mark</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="Image" alt="V" /></td>
<td>Mark indicating Energy Power Supplies meets the level V requirements at <strong>both 115 V/60 Hz and 230 V/50 Hz</strong>. As the devices meet the requirement and it can run at multiple voltage therefore, the mark do not have to indicate the voltage.</td>
</tr>
<tr>
<td><img src="Image" alt="IV" /></td>
<td>Mark indicating Energy Power Supplies meets the level IV performance requirements only at <strong>115 V/60 Hz</strong> (for EPSs also able to operate at 230 V/50 Hz). Therefore since it can only run at one of the voltages therefore the mark have to indicate which voltage does the device run</td>
</tr>
<tr>
<td><img src="Image" alt="IV" /></td>
<td>Mark indicating Energy Power Supplies meets the level IV requirements at <strong>only 230 V/50 Hz</strong>. Therefore since it can only runs at one of the voltages therefore the mark have to indicate which voltage does the device run</td>
</tr>
<tr>
<td><img src="Image" alt="IV" /></td>
<td>Dual marking for EPS that meets different performance levels at different input voltages.</td>
</tr>
</tbody>
</table>

Figure 7 shows the significance information of each mark (retrieved September 02, 2015 from https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/International_Efficiency_Marking_Protocol.pdf)
RECENT DEVELOPMENT IN ENERGY EFFICIENCY REGULATION

The implementation of new energy efficiency level VI will go into force on February 2016, it is the new U.S Level VI energy efficiency regulation. The new level VI regulation has two major components in which the first one is the adding of new range of products under standard of multiple voltages external power supplies and the products with power level up to 250 W. And the second one is that the new regulation emphasized the people to conserve power in consumer and industrial type product but power supplies related to medical purposes are not included or exempt to the new regulation law.

Andrew Johnson the product manager for external power supplies of CUI Inc Company also said that the new regulation is increased by 5 percent. The new changes also being mentioned for no-load such that when a cell phone charger is connected to the wall but no mobile cell phone connected to the charger the power consumption is only 0.1 W while in the energy efficiency level V regulation the power consumption would be 0.5 W.