Alternative Power Generation for Subsea Production System

By

Muhammad Fadhil Bin Hassan Basri

Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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(Assoc. Prof. Dr. Fakhruldin Mohd Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD FADHIL BIN HASSAN BASRI

ABSTRACT

This project is intended to propose a concept system of an alternative power generation for subsea power generation system. The main reasoning for the concept to be proposed is to eliminate the need of powering SPS from long distance or from the topside since this will cause power loss and high cost in long umbilical. This project will utilize the ocean current as the alternative energy source of the power generation because it will be placed on the seabed, near the SPS facilities. Therefore ocean current is suitable to be exploited for this task. Using morphological approach, several concepts will be produced based on the extractor types, and it will be evaluated. The chosen concept design will be the proposed concept design for alternative power generation, which is the output of this project. It will be evaluated for suitability in powering the SPS and also the assembly drawing of the proposed concept design is presented in the results and discussion section.

ACKNOWLEDGMENT

First and foremost I would like to express my highest gratitude to Allah S.W.T, which has been guiding and supporting me throughout my entire life in general and during taking this project in specific.

I would like to express my gratitude toward my FYP supervisor, Assoc. Prof. Dr. Fakhruldin Mohd Hashim for his continuous belief in my ability to conduct this project. His continuous supports and advices are very crucial in completing the FYP project. Without his efforts, this project would be nowhere until today. I appreciate his effort and time to assist me in doing the reports and giving me assistance.

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Thank you.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The petroleum industries are now moving toward the subsea technology for oil and gas production. The demand of using the latest subsea facilities are now high as it is the most cost effective means for marginal field development (Crick, Bosley, 1993). Furthermore the substantial depletion of exploitable oil and gas deposits in shallow waters has increased the interest of the petroleum industry to make their move toward reserves at deeper depth. To achieve that, the development of subsea production system technology is going at full speed to enable the exploitation of deepwater reserves with success. For this project, the main aim is to design a power generation system to supply the required power for an All-Electric Subsea production system, at an acceptable cost yet high in reliability to support the development of the all-electric (hydraulics-free) subsea technology. In this case, the CameronDC™ SPS is taken as a reference load for the power generation. Marine or ocean current is chosen for the alternative energy for the project since the power generation is needed as close as possible to the SPS.

1.2 PROBLEM STATEMENT

To power up the SPS from long distance power source can be uneconomical. For large step out distances (>30km), over 50% of the power supplied from the topsides will be lost in the umbilical (Stavropoulos, M. et al., 2003). Therefore to supply power at further distance, power generation requirement will increase to compensate losses thus increasing the overall cost. Therefore, a design of power generation system is needed to avoid high loss caused by long distance power supply. A localized power generation system design is suggested for countering the problem.

1.3 OBJECTIVES

The objectives of this project will be:

1) To produce concept designs of alternative power generation for subsea production system.
2) To produce the corresponding assembly drawing of the selected concept design.
3) To evaluate the suitability of the proposed concept design.

1.4 SCOPE OF WORK

The scope of work for this project will be on the study of the CameronDC^{TM} power requirement, gathering information on power generation technology for subsea applications and designing the power generation system that fit the power requirement for the CameronDC^{TM}.

1.5 RELEVANCY OF THE PROJECT

This project serves as a supporting effort in all-electric subsea production system development which will be the future of oil and gas industry because the increasing demands in exploration in deepwater and remote territory.

1.6 FEASIBILITY OF THE PROJECT

The project is a design-based project which is feasible to be done without the need of special instruments of equipment. The activity will be more on research, designing and evaluating which is within the scope of the project and the time frame of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Subsea production system (SPS)

(Bai Y.) A subsea production system consists of a subsea completed well, seabed wellhead, subsea production tree, subsea tie-in to flowline system, and subsea equipment and control facilities to operate the well. It can range in complexity from a single satellite well with a flowline linked to a fixed platform, FPSO (Floating Production, Storage and Offloading), or onshore facilities, to several wells on a template or clustered around a manifold that transfer to a fixed or floating facility or directly to onshore facilities. As the oil and gas fields move further offshore into deeper water and deeper geological formations in the quest for reserves, the technology of drilling and production has advanced dramatically. Conventional techniques restrict the reservoir characteristics and reserves that can be economically exploited in the deep waters now being explored. The latest subsea technologies have been proven and formed into an engineering system, namely, the subsea production system, which is associated with the overall process and all the equipment involved in drilling, field development, and field operation.The subsea production system consists of the following components:

- Subsea drilling systems;
- Subsea Christmas trees and wellhead systems;
- Umbilical and riser systems;
- Subsea manifolds and jumper systems;
- Tie-in and flowline systems;
- Control systems;
- Subsea installation.

2.2 SPS control system

The fundamental purpose of a control system is to open and close valves. However, other properties, such as instrumentation, provide chock control and important diagnostics.

The five types of fundamental control systems are:

- Direct hydraulic;
- Piloted hydraulic;
- Sequenced hydraulic;
- Multiplex electrohydraulic;
- All-electric.

Since the 1960s, the evolution of control system technology has proceeded from direct hydraulic to piloted and sequenced systems to provide improved response time and allow for long-distance tie-backs. Now, most subsea developments use the multiplex electrohydraulic (EH-MUX) control system. This is essentially a subsea computer/communication system consisting of hydraulic directional control valves. These electrically actuated valves allow stored pressure within subsea accumulators to be routed to individual hydraulic lines and onward to actuated gate valves and chokes on subsea production equipment. All-electric control systems are an attractive addition and an alternative to existing electrohydraulic systems. The all-electric subsea electric controls will reduce the cost of topside power generation and subsea umbilicals. (Bai Y., Bai Q.). For this project, we are concerning on the latest technology which is the All-Electric SPS.

2.3 All-Electric Control System

The all-electric control system requires conversion from a system where control is based on conventional hydraulic control of subsea components to an all-electric–based system. The elimination of hydraulics means that any control system commands are sent in rapid succession without the usual lag time required for accumulators to charge. This system is typically used incomplex fields and marginal fields of long distances (usually greater than 5 km) and for high-pressure and high-temperature wells. To open a tree valve, the operator operates the MCS to request the valve movement. The MCS sends a coded message to the SEM, which interprets the message and energizes the appropriate relay operated pilot relay, allowing electric power to energize the tree valve actuator. The benefits of using all-electric control systems are very clear. An all-electric control system is expected to be simpler compared to a conventional electrohydraulic control system. It is favorable to use when developing marginal fields at great distances from a processing facility because of the lower cost of umbilicals, and it also provides solutions to problems associated with high-pressure and high-temperature wells because there is no need for hydraulic fluid. Further, it provides a higher degree of flexibility when expanding an existing system and when introducing new equipment into the system. Finally, the removal of the hydraulic system omits environmental and economic problems related to the leakage of hydraulic control fluids and the complexity of working with hydraulics (Bai Y., Bai Q.)

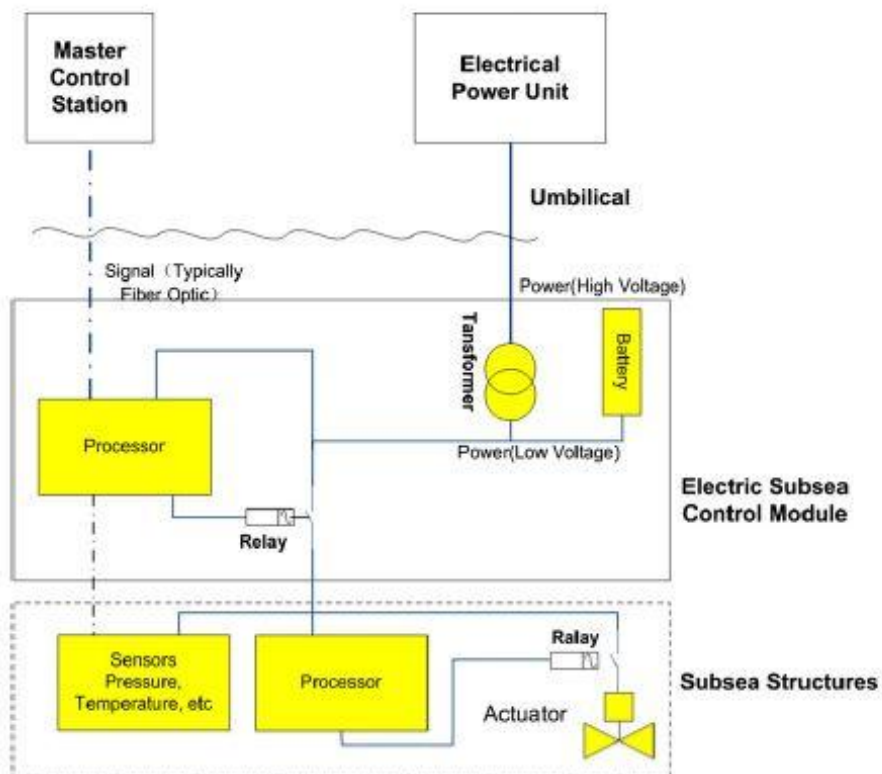


Figure 2.1: All-Electric system (Bai Y., Bai q.)

The power requirement of All-Electric SPS is basically only in the range of several kilowatts.

Operation	Type	Power requirement	Freq. (/day)	duration
single valve actuation	Momentary	3-5 kW	1-3	45-60 sec.
single valve normal operation	Continuous	20-50 W	-	-
choke valve actuation	Momentary or continuous	1-2 kW (mom) 60 W (cont)	n/a	45-60 sec (mom)
SEM	Continuous	Max of 80 W	-	-
Sensors	Continuous	Max of 50 W	-	-

Table 2.1: All-Electric SPS power requirement schedule (Stravropoulous M. et al, 2003)

2.4 CameronDC SPS

The CameronDC™ system is an all-electric subsea production system which is developed by Cameron. The system had been deployed in the North Sea in 2008 for K5F project and gave feedbacks exceeding expectation with overall system availability of well above 99% had been attained (Abicht, 2010). Comparing to the conventional electrohydraulic multiplex (EH MUX) system, CameronDC™ has faster system start-up and can be deploy fast. The second well in K5F project was commissioned in less than 24 hours (Carter, 2009). CameronDC™ system revolutionized the subsea production by having a system with the absent of hydraulics, batteries, accumulators and also no moving parts inside the subsea control module. Without these elements, the system is highly reliable (Cameron, 2011). With the success on the K5F project, CameronDC™ system is now available in the 2nd generation with increased functionality and benefits. The 2nd generation system can control up to 32 electric actuators per electric subsea control module (eSCM) compared to only 16 by the pilot system.

Figure 2.2: CameronDC™ All electric subsea tree (Cameron, 2011)

This system consumes voltage levels up to 6kVDC with power demand in the range of kilowatts. Power is received at the templates and regulated down to 300 VDC for control and actuation system applications. Standard power requirements are ranging from 1 to 10 kilowatts per template (Menz, 2006).

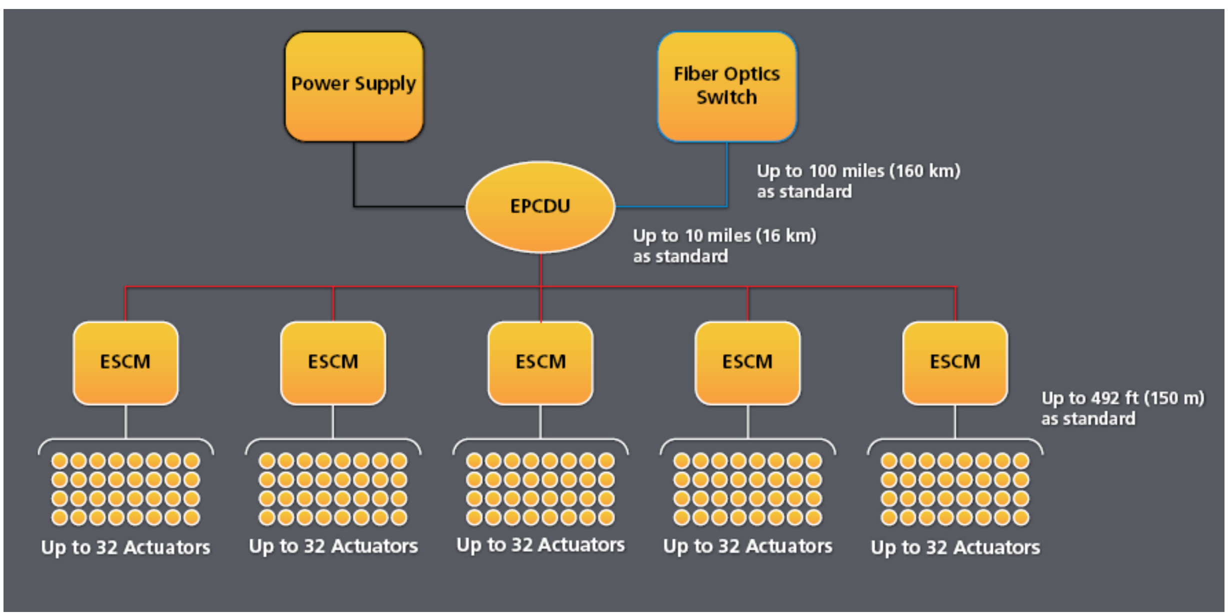


Figure 2.3: CameronDC™ 2nd generation concept (Cameron, 2011)

2.5 Effect of the umbilical on the cost

Localized power generation system is a system that generates power to be supplied equipment and facilities within its vicinity, with the main objectives of maximizing the efficiency of power supply while reducing the cost. The cost for subsea facilities is being affected heavily on the umbilical issue. Umbilical is a cable bundle which supplies hydraulic and electrical power, as well as necessary chemical to any subsea facility. Research find that umbilical, combine with flowlines, and represent the largest cost item in the post drilling phase of the production system (Stavropoulos, et al., 2003). This fact is also consistent with another observation that claims all electric systems provide CAPEX savings from reduced umbilical, which show how cost can be reduced by manipulating umbilical (Sten-Halvorsen, Koren, 2008).

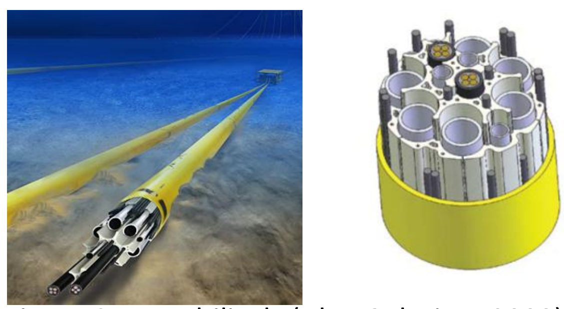


Figure 2.4: Umbilicals (Aker Solution, 2009)

2.6 Power generation Method for Subsea facilities

Various way of generating power to subsea facilities locally had been suggested to reduce the cost on having long distance umbilicals for power supply apart from to reduce the losses on power transmission. For example, the concept of using natural gas to generate power via floating power plant seems to be economically viable, but still need thorough study (Hill, J. et al, 2002). There are also suggestions of having natural-moved turbines for subsea power generation. There is a study that introduces the prospect of generating power for a subsea production system using marine current turbines to generate 1 to 10kW, at seabed level (Stavropoulos, et al., 2003). Whereas another study affirm positive feasibility of supplying power to remote subsea development using a moored, wind turbine which may generate power ranging from 2 to 5 MW (Thornton, 2002). There are varieties of patents available on power generation system at offshore location. For example, a patent of offshore compound renewable energy power plant which incorporated both wind and ocean power as the source (Young et al, 2012). Another example is offshore power generator which is focusing on harvesting power from currents, wave, or alternative generators (Gehring, 2008). Figure 2 & 3 shows the illustration of the system from these patents. Therefore a wide variety of power source that can be exploit for the power generation system especially from the renewable energy.

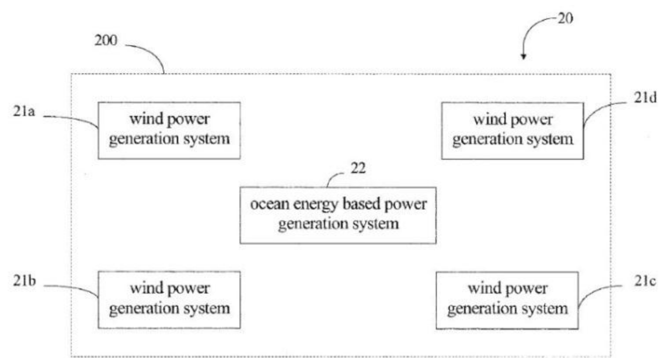


Figure 2.5: Offshore compound renewable energy power plant (Young et al,

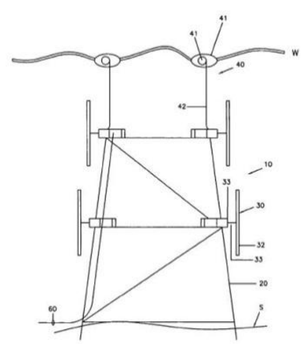


Figure 2.6: Offshore power generator with currents and wave source (Gehring, 2008)

2.7 Harvesting energy from ocean current

This project is focusing on the ocean current energy. Ocean current has a very good potential in generating power for offshore and subsea application. Ocean current has several distinctive characteristic that need to be considered of while coming up with the concept system that tapping into its energy. Ocean currents are so predictable and the movement can be predicted years ahead unlike the wind movement. It also possess very high energy density compared to the wind energy since liquid are much denser than air. Therefore the extractor such as turbine can be much smaller compared to wind turbine in order to harness same amount of energy (Breeze, 2005). However ocean current is subjected to the Ekman spiral effect where the motion of wind above the seawater sets spiraling motions in in horizontal column. This shows that the marine current direction deflects and changes direction as the depth increase. The Ekman spiral is basically caused by the coriolis effect which subjects moving objects to a force to the right of their direction of motion in the northern hemisphere and to the left in the Southern Hemisphere (DataStreme Ocean).

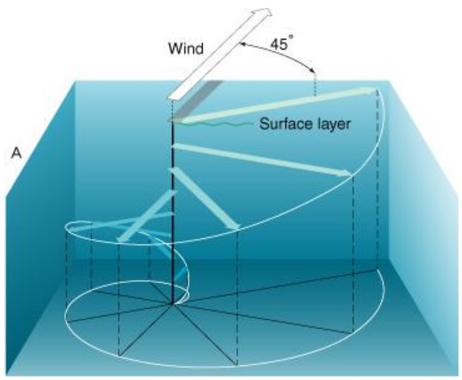


Figure 2.7: Ekman Spiral (DataStreme Ocean)

Another important characteristic is that ocean current speed decreased with the increasing depth of the ocean (Cook G.S., 1963). The power that can be harvest therefore will be greater at shallow depth due to higher speed of the current.

Area	Drogue Depth (meters)	Range of Speeds (cm/sec)	Average Speed (cm/sec)	Total Tracking Time (hours)	Direction
D10	8	37.0 - 7.0	9.5	25	SW
	100	35.0 - 1.5	8.0	24.7	NW,SW
	500	8.0 - 4.5	6.5	18.3	WSW,WNW

Current speeds generally decreased with increasing depth. The directions, however, were quite variable.

Figure 2.8: Depth, current speeds and direction table (Cook G.S, 1963)

A US patent of Ocean Current Power Generator (Haining, 1995) showed a hydroelectric power plant which comprises several combination turbine/generators which are suspended into an ocean current from a submerged tension leg type platform. Each of the the turbine/generators are independently positionable horizontally, vertically and azimuthally to take the best advantage of the current.

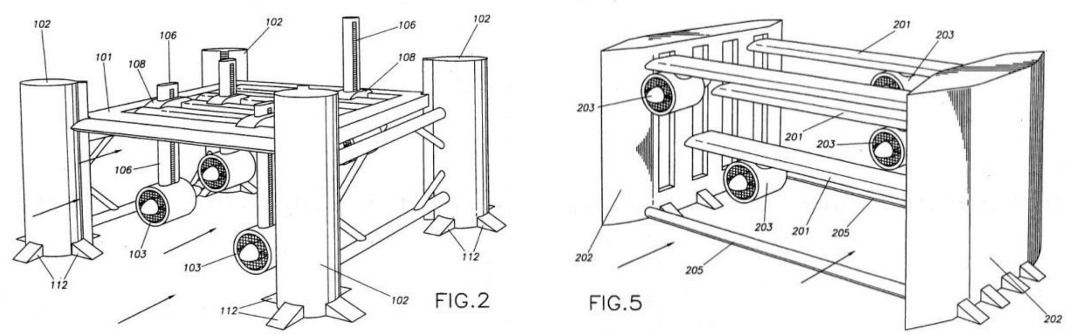


Figure 2.9: Ocean Current Power Generator (Haining, 1995)

Another US patent for ocean current power generation is the Energy Harvesting Eel (Carroll, 2002) which uses piezoelectric power generator. It comprises an elongated, flexible central layer of a dielectric material having spaced axially along opposite sides thereof, a plurality of separate piezoelectric elements each formed from a portion of a continuous layer of piezoelectric layer extending along each opposite side of the central layer sandwiched between a pair of electrodes unique to each piezoelectric element.

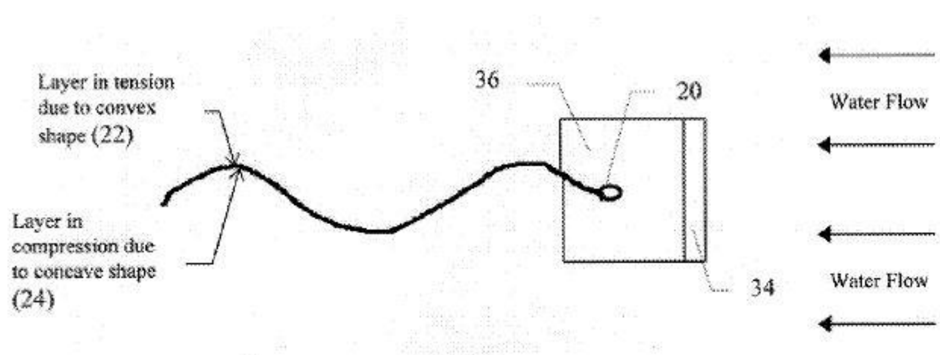


Figure 2.10: Energy Harvesting Eel (Carroll, 2002)

A relatively simple but powerful system to extract ocean current is by using Rotech Tidal Turbine (Lunar Energy, 2010), a horizontal axis turbine (HAT) which being able to harness the energy of fast-moving deep sea streams and it is positioned on the seabed using three gravity legs base and able to produce 1MW of power per unit.

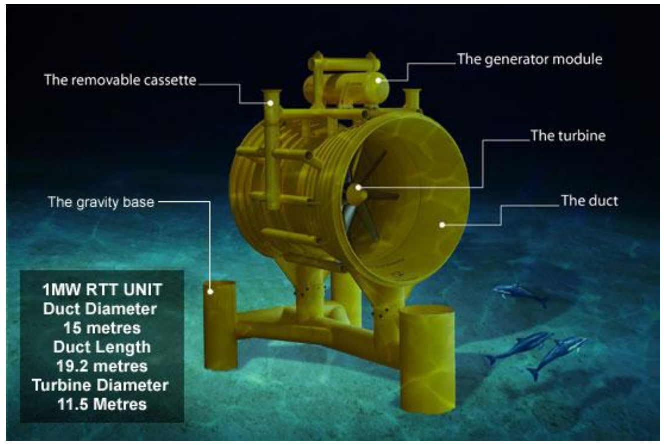


Figure 2.11: Rotech Tidal Turbine (Lunar Energy, 2010))

Another means of harnessing ocean current energy is by using Vortex Induced Vibration for Aquatic Clean Energy or VIVACE (Bernitsas M. et al, 2006) which exploit vortex induced vibrations (VIV) to generate energy with high power conversion ratio from a fluid flow. The design is based on the very simple idea of enhancing rather than spoiling vortex shedding and maximizing under significant damping rather than suppressing VIV. It can use several type of generator for example, by using electromagnetic to produce electric.

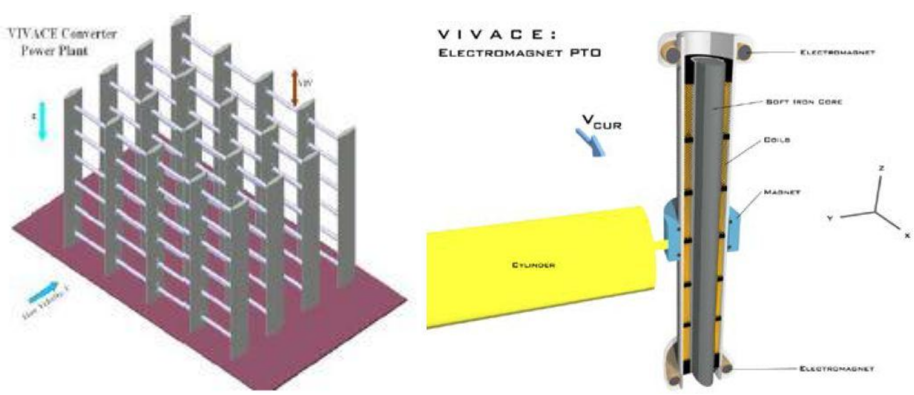


Figure 2.12: VIVACE converter power plant (Bernitsas M. et al, 2006)

Hydroplane can also be a mean of extracting energy. Stingray is a system designed to extract useable electricity from currents. It differs from other proposed devices in that it uses an oscillating motion rather than rotation to capture the energy from the tidal flow. The main feature of Stingray is the wing-like hydroplane and it is attached to a supporting frame by a moveable arm. The supporting frame is seabed mounted. As currents pass over the hydroplane, lift and drag forces cause the hydroplane to lift, actuating hydraulic cylinders at the arm/frame junction. The high pressure oil developed by the cylinders turns a hydraulic motor which drive an electric generator. When the hydroplane and arm reach their upper limit, the hydroplane angle is reversed such that the arm is driven down and the cycle repeated (DTI, 2005).

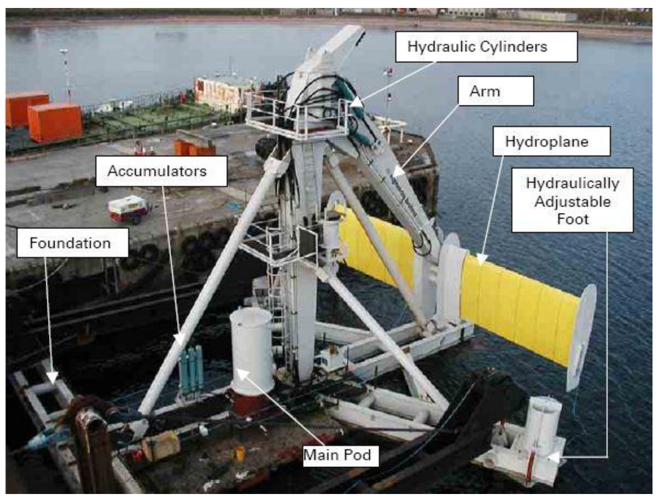


Figure 2.13: STINGRAY assembly (DTI, 2005)

2.8 Potential of existing power system technology for subsea application

A table has been compiled after discussions with suppliers of the corresponding components that ensured the transferability of their technology for seabed operation in all cases, with the exception of turbines, the suppliers of which were confident that the technology was transferrable, subject to further development (Stavropoulous M. et al, 2003)

Component/Technology	Function	Seabed Operation
EPU	Power Conditioning	Yes
Rectifiers	AC to DC conversion	Yes
Inverters	DC to AC conversion	Yes
HPU	Hydraulic Power Generation	Yes
Generators	Electro-mechanical Conversion	Yes
Batteries / Charging and Discharging Systems	Energy Storage	Yes
Turbines	Power extraction from marine currents	Further Development required
System Installation		Mature technology

Table 2.2: Existing technology and potential for transfer to seabed level (Stavropoulos M. et al, 2003)

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

In order to achieve the main objective of the project, research and study on related matters are to be carried out prior to the submission of preliminary report. Technical papers from several petroleum societies (OTC, SPE, and SUT) are to be studied to gather information regarding SPS and available power generation technology for subsea application. Apart from technical papers, textbook reference on the designing steps also will be included for reference.

3.2 PROJECT FLOW

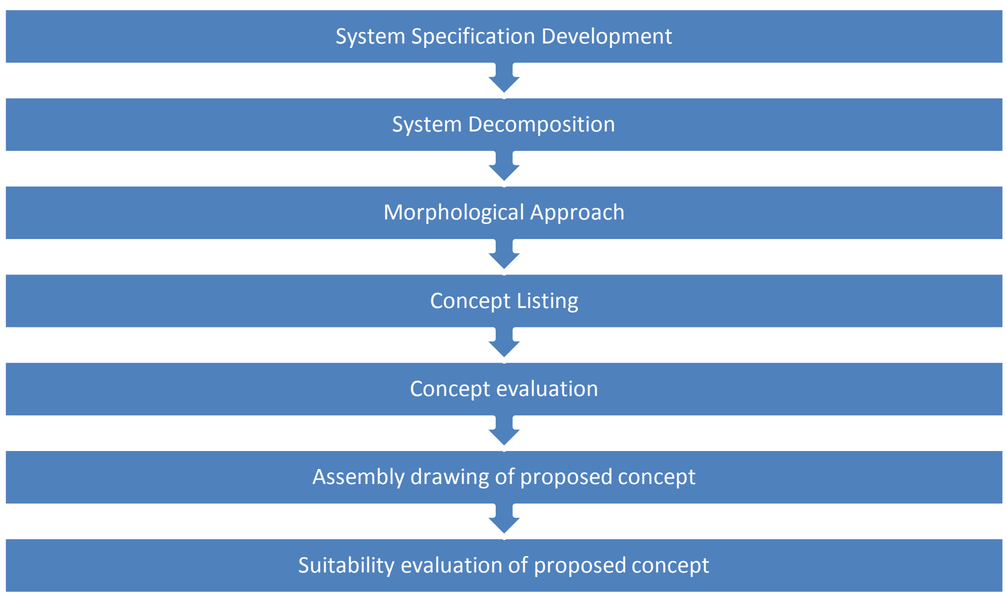


Figure 3.1: Project methodology flow

3.2.1 System Specification Development

In this stage, the specifications of the power generation system are developed in order for the concepts to be produced according to the need. The specification will take the characteristic of ocean current into consideration.

3.2.2 System Decomposition

The power generation system will be decomposed into several elements in order to clarify every sub-element that comprises in the system. The system decomposition will also be the guide in generating the concept system using morphological approach.

3.2.3 Morphological Approach

Using this approach, a morphology chart comprise of elements in the system will be constructed based on the system specification developed beforehand. The chart will then assist the generation of system concepts.

3.2.4 Concept Listing and Evaluation

In this stage the concepts will be generated using the morphology chart and every concept generated will have its own rational and reasoning. The concepts will then being evaluated using weighted decision matrix and the highest scoring concept will be the proposed design for powering SPS.

3.2.5 Assembly drawing of the proposed concept

Assembly drawing of the proposed concept will be presented and it will comprise mostly the layout of the concept system' elements for visual understanding. The drawing will be done using CATIA V5.

3.2.6 Suitability evaluation of proposed concept

The evaluation of suitability will be done by comparing the proposed concept design with existing system and patent. The governing equation will be associated with the proposed system in evaluating the suitability of it.

3.3 Gantt Chart

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic							Mid Semester Break							
2	Preliminary research work														
3	Submission of extended proposal														
4	Proposal Defense														
5	Further research work														
6	Submission of Interim Draft Report														
7	Submission of Interim Report														

Table 3.1: FYP 1 Gantt Chart

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	System Specification Development							Mid Semester Break								
2	Submission of Progress Report															
3	System Decomposition															
4	Morphological Approach															
5	Concept Listing															
6	Concept Evaluation															
7	Proposed Concept Assy Drawing															
8	Proposed Concept Evaluation															
9	Pre EDX															
10	Submission of Draft Report															
11	Submission of Dissertation															
12	Submission of Technical Paper															
13	Oral Presentation															
14	Submission of Project Dissertation															

Project Work Progress

Project Milestone

Table 3.2: FYP 2 Gantt Chart

CHAPTER 4

RESULTS & DISCUSSION

4.1 System Specification Development

4.1.1 General design requirement.

For general design requirement, the system will follow NORSOK standard for SPS. The requirements are:

- Subsea systems should be designed for diverless installation and intervention.
- Diving operations shall not be planned in water depths exceeding 180 m.
- The subsea production system shall be designed to optimize life cycle cost within the defined safety level.
- All pressure containing equipment shall be rated to the highest system operating or test pressure.
- For pressure containing equipment placed subsea the design pressure may be adjusted for hydrostatic pressure.
- The sub system design work should include the definition of all interfaces between subsystems, typically listed in clause 4.1.
- The system shall be designed for easy fault diagnosis without system retrieval.
- A high system availability should be obtained through use of simple designs and high quality products (suppliers standard equipment with an in field performance record). Use of redundant designs should only be selected after a cost/benefit analysis.
- Operational reliability shall be documented for the subsea systems.
- For non-critical temporary equipment relaxed requirements may be accepted.
- Intervention interfaces shall be implemented according to international standards. (e.g. API 17H)

- Connectors with critical functions shall have an arrangement preventing unintentional release.

Other specifications related to the performance of the system are:

- Minimum power supply of 10kW
- Depth of operation: must be greater than 180m / at seabed
- Location of operation: <1km radius of the powered SPS
- Using Supervisory Control and Data Acquisition (SCADA) or Distributed Control System (DCS) for control and monitoring the power generation system.
- Able to generate power with the slow moving current on seabed level.
- The system will directly supply the power from subsea level.

4.2 System Decomposition

The power generation system consists of four major units which are the Power Generation Unit (PGU), Energy Storage Unit (ESU), Electrical Power Distribution (EPD) and System Control Unit (SCU). These units have its own set of task in order for the system to generate and supply electrical power to the CameronDC™ SPS. PGU is the main unit where raw energy from the ocean currents is being extracted using the extractor(s). SCU will control the power in all aspect in term of usage, conditioning, conversion, charging and discharging of power. It also serves to monitor and control the system. ESU will store the excess power and to be supplied to the load as uninterruptible power supply (UPS). ESU is really important for a renewable energy system because the power harvested often fluctuates and non-constant. EPD will be responsible for distribution for the electrical power to the load.

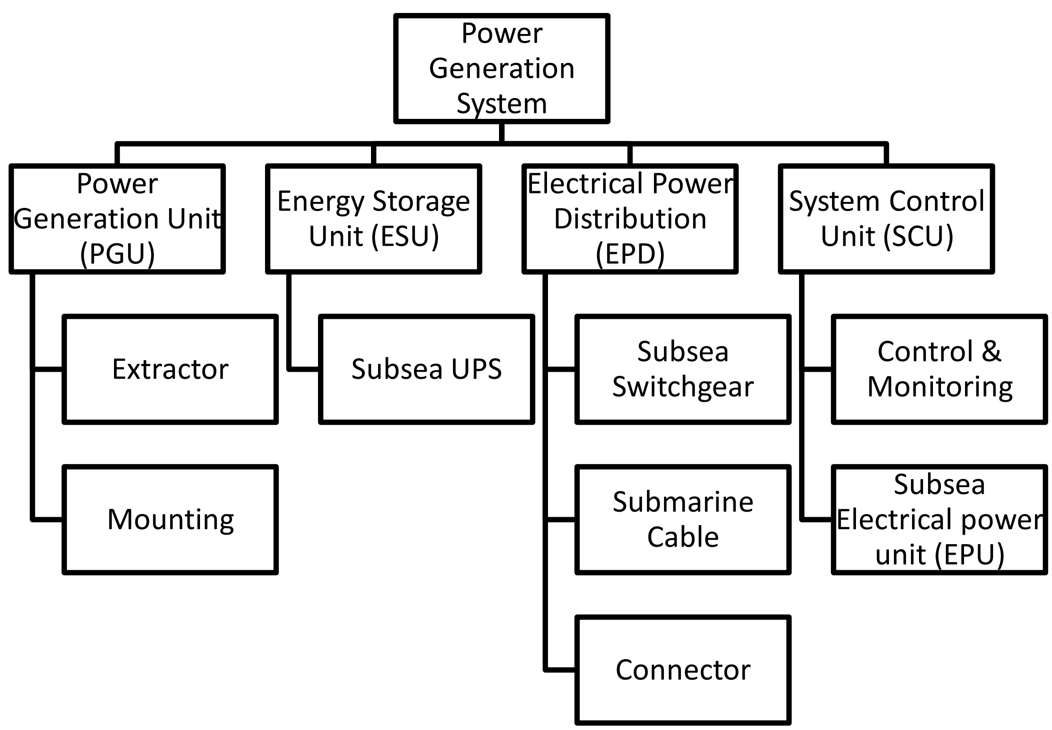
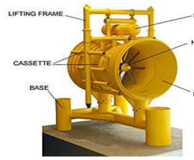
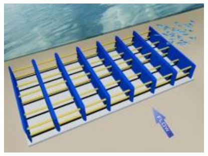
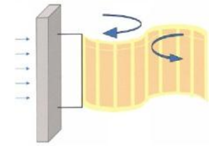
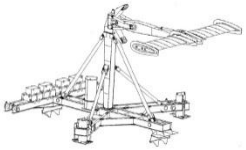
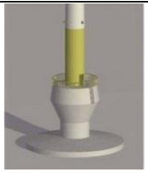


Figure 4.1: System Decomposition

4.3 Morphological Approach

In morphology chart, choice of options for the system composition will be listed. The items are based on type of the elements that available for selection.

SUBSYSTEM	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
POWER GENERATION UNIT (PGU)					
Extractor	 Rotech Tidal Turbine system	 Davidson Hill Venturi Turbine System	 VIVACE system	 EEL system	 STINGRAY system
Mounting	 Monopile	 Gravity based	 Suction pile	 Tripod	
ENERGY STORAGE UNIT (ESU)					
Subsea UPS	Standby	Line Interactive	Standby-Ferro	Double Conversion	Delta Conversion
ELECTRICAL POWER DISTRIBUTION (EPD)					
Subsea Switchgear	Oil circuit breaker	 Gas circuit breaker	 Vacuum circuit breaker		

Submarine Cable	 XLPE cable	 Mass Impregnated cable	 Light cable		
Connector	 Wet Mateable	 Dry Mateable			
SYSTEM CONTROL UNIT (SCU)					
Control & Monitoring	SCADA	DCS			
Subsea EPU	Single DC Output	Dual DC output			

Table 4.1: Morphology chart

4.4 Concept listing

From the morphology chart, concepts can be generated. The difference between concepts is mainly on the power generation unit since every sub-system can be fixed for every concept. For the SCU, SCADA is chosen for the control and monitoring because it is a common tool and being used worldwide for its ability to monitor and control entire system. For subsea EPU, Dual DC output will be suitable for the system since it can simultaneously supply power to the load and charge the battery. For subsea switchgear, the vacuum circuit breaker type is chosen due to its suitability operation on subsea condition. Wet mateable connectors are good for assembling the system underwater. For ESU, Delta conversion subsea UPS is chosen for its high efficiency in supplying constant power to the load. All of the subsea equipment has their own pressurize encapsulation to enable them to operate at high pressure condition, which is the seabed. There will be 5 concepts to be generated from the morphology chart.

4.4.1 Concept A

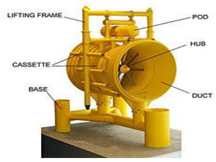
No	Subsystem	Item	No	Subsystem	Item
1	POWER GENERATION UNIT		3	ELECTRICAL POWER DISTRIBUTION	
	Extractor	 Rotech Tidal Turbine system		Subsea Switchgear	 Vacuum circuit breaker
	Mounting	 Gravity based		Cable	 Light cable
2	SYSTEM CONTROL UNIT			Connector	 Wet Mateable
	Control & Monitoring	SCADA	4	ENERGY STORAGE NUIT	
	Subsea EPU	Dual DC output		Subsea UPS	Delta Conversion

Table 4.2: Concept A

This concept uses Rotech Tidal Turbine (RTT) system, which comprise of venturi ducted horizontal turbine and generator module. The turbine blade is assembled on a removable cassette which eases the maintenance of the turbine. The turbine is secured to its position on the seabed level using gravity base. This concept is very simple in term of design and working principle which is as the same as wind turbine. The venturi duct increases its capability on generating power and need not to yaw.

4.4.2 Concept B

No	Subsystem	Item	No	Subsystem	Item
1	POWER GENERATION UNIT		3	ELECTRICAL POWER DISTRIBUTION	
	Extractor	 Davidson Hill Venturi Turbine System		Subsea Switchgear	 Vacuum circuit breaker
	Mounting	 Tripod		Cable	 Light cable
2	SYSTEM CONTROL UNIT			Connector	 Wet Mateable
	Control & Monitoring	SCADA	4	ENERGY STORAGE NUIT	
	Subsea EPU	Dual DC output		Subsea UPS	Delta Conversion

Table 4.3: concept B

This concept uses Davidson-Hill Venturi (DHV) turbine system which comprise of Venturi Shrouded Vertical turbine and generator module. The DHV turbine design is focusing on increasing the speed of current entering the turbine using the venturi shroud, thus harnessing more energy. The shroud also functions to protect the turbine from being damaged by debris from the current. The DHV turbine system will be deployed on tripod mounting to increase the stability on its position. The concept is simple in design and also the DHV can be easily transport to the site since it is manufactured in flat pack shape.

4.4.3 Concept C

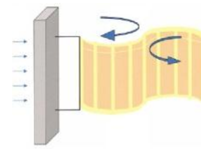
No	Subsystem	Item	No	Subsystem	Item
1	POWER GENERATION UNIT		3	ELECTRICAL POWER DISTRIBUTION	
	Extractor	 EEL system		Subsea Switchgear	 Vacuum circuit breaker
	Mounting	 Tripod		Cable	 Light cable
2	SYSTEM CONTROL UNIT			Connector	 Wet Mateable
	Control & Monitoring	SCADA	4	ENERGY STORAGE NUIT	
	Subsea EPU	Dual DC output		Subsea UPS	Delta Conversion

Table 4.4: Concept C

This concept uses EEL system which comprise of flexible piezoelectric power generator. The design is very simple and easy to deploy. Multiple piezoelectric power generators can be mounted on the same tripod base since it is lightweight and does not take much space.

4.4.4 Concept D

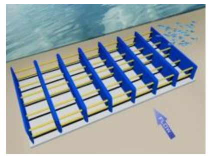
No	Subsystem	Item	No	Subsystem	Item
1	POWER GENERATION UNIT		3	ELECTRICAL POWER DISTRIBUTION	
	Extractor	 VIVACE system		Subsea Switchgear	 Vacuum circuit breaker
	Mounting	 Gravity based		Cable	 Light cable
2	SYSTEM CONTROL UNIT			Connector	 Wet Mateable
	Control & Monitoring	SCADA	4	ENERGY STORAGE NUIT	
	Subsea EPU	Dual DC output		Subsea UPS	Delta Conversion

Table 4.5: Concept D

This concept utilizes the VIVACE system for the PGU. It comprises of Vortex cylinders and vertical electromagnet generator. The concept has good advantage on seabed level because it has a very high power conversion from fluid flow since the current speed on seabed is not so high. The VIVACE system will be positioned on gravity based mounting since it needs wide adea to place the cylinder facing the current.

4.4.5 Concept E

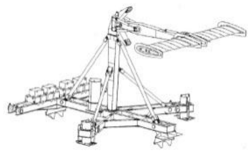
No	Subsystem	Item	No	Subsystem	Item
1	POWER GENERATION UNIT		3	ELECTRICAL POWER DISTRIBUTION	
	Extractor	 STINGRAY system		Subsea Switchgear	 Vacuum circuit breaker
	Mounting	 Tripod		Cable	 Light cable
2	SYSTEM CONTROL UNIT			Connector	 Wet Mateable
	Control & Monitoring	SCADA	4	ENERGY STORAGE NUIT	
	Subsea EPU	Dual DC output		Subsea UPS	Delta Conversion

Table 4.6: Concept E

This concept uses STINGRAY system which comprise of Hydroplane arm and hydraulic motor for its power generation. The STINGRAY hydroplane arm uses drag and lift force created from the ocean current to generate power from its hydraulic motor. The STINGRAY system is mounted on the tripod mounting to increase its stability on the seabed.

4.5 Concepts evaluation

All the concepts are evaluated using weighted matrix scoring with 11-points scale. For the matrix, several criteria are set to be taken into consideration. The criteria are derived from objective tree which classified the criteria into 2 major category namely performance and sustainability of the system.

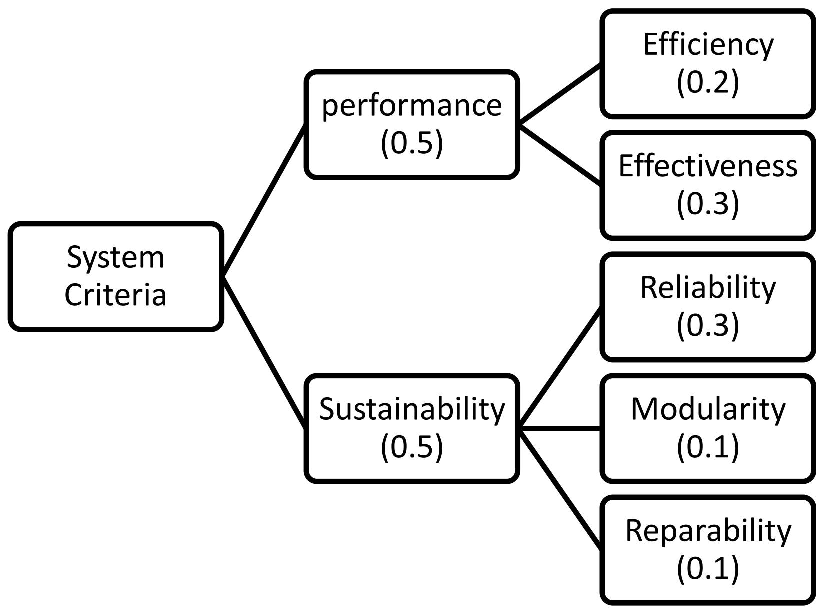


Figure 4.2: Objective Tree

The performance and sustainability of the system are given 0.5 weight factor in order to achieve balance between both categories. The performance category consist of efficiency (0.2) and also effectiveness (0.3) where the performance of the system will be based on how well it will do its job. The sustainability category consist of reliability (0.3), modularity (0.1) and also reparability (0.1) where the sustainability of the system rely on the ability of the system to operate and function for a certain time as well as being able to be recycled (use again/transport to other site).

The criteria are:

1. Reliability:

   The criteria stress on probability of the system to function over time. This criteria is important to ensure the system will not easily break down
2. Efficiency:

   The efficiency of the system in converting the power from source into useful energy
3. Effectiveness:

   The criteria demand for the system to do its intended function completely and accordingly.
4. Modularity:

   The criteria stress on easy installation and assemble/disassemble of the system for future displacement/transportation of the system
5. Reparability:

   The criteria stress on the availability of the system to be repaired in case of break down/ problem.

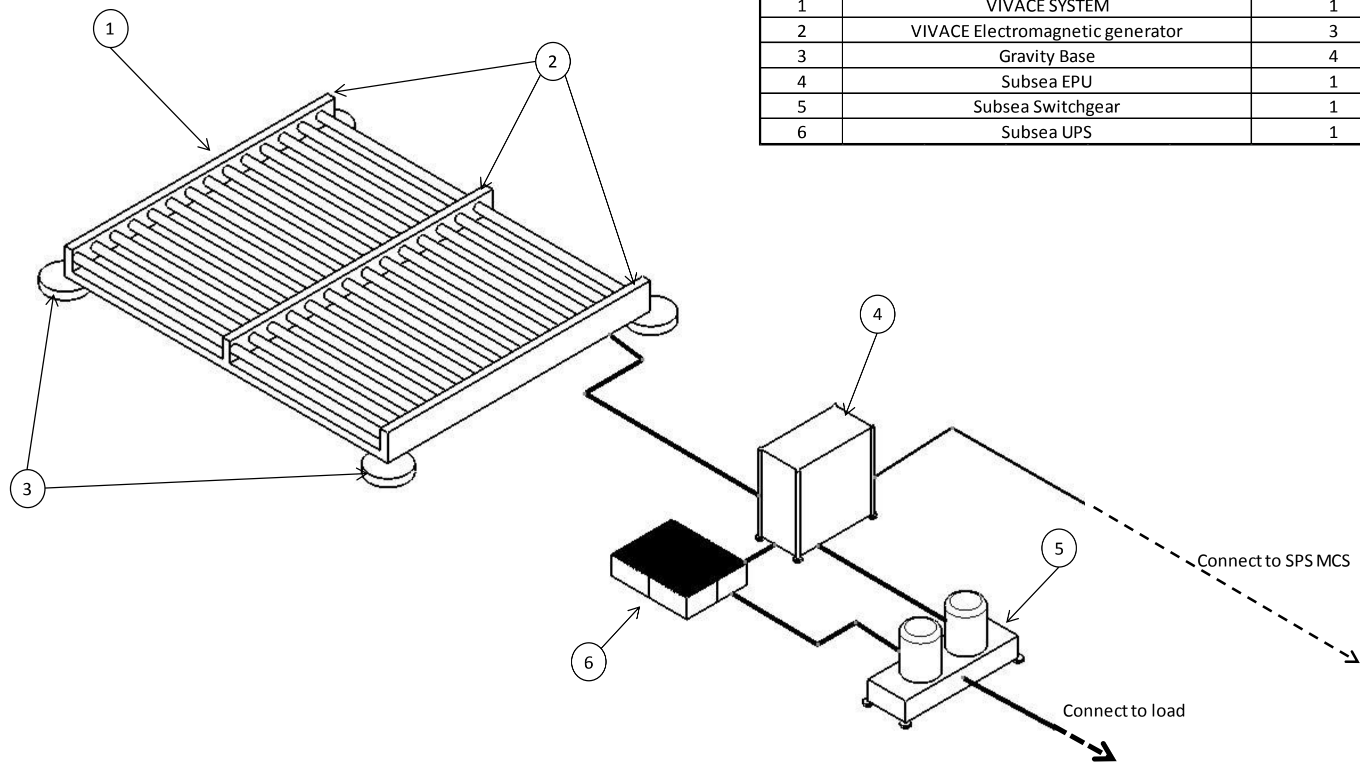
Design Criteria	Weight Factor	A score	A rating	B score	B rating	C score	C rating	D score	D rating	E score	E rating
Efficiency	0.2	6	1.2	7	1.4	5	1	8	1.6	5	1
Effectiveness	0.3	9	2.7	9	2.7	7	2.1	9	2.7	6	1.8
Reliability	0.3	8	2.4	8	2.4	9	2.7	8	2.4	4	1.2
Modularity	0.1	7	0.7	8	0.8	9	0.9	8	0.8	5	0.5
Reparability	0.1	7	0.7	7	0.7	5	0.5	7	0.7	7	0.7
Total Rating			7.7		8.0		7.2		8.2		5.2

Table 4.7: weighted matrix scoring for concepts

Based on the evaluation, concept D produced the highest score among all other concept with the score of 8.2. Therefore Concept D is chosen as the proposed design.

4.6 Assembly drawing of the proposed concept

BILL OF MATERIALS		
NO	Equipment	Quantity
1	VIVACE SYSTEM	1
2	VIVACE Electromagnetic generator	3
3	Gravity Base	4
4	Subsea EPU	1
5	Subsea Switchgear	1
6	Subsea UPS	1



TITLE: ALTERNATIVE POWER GENERATION SYSTEM			A4
DRAWN BY: FADHIL	SCALE 1:100	SHEET NO: 1/1	

Figure 4.3: Assembly drawing of the proposed concept

4.6.1 Working principle of Proposed Concept

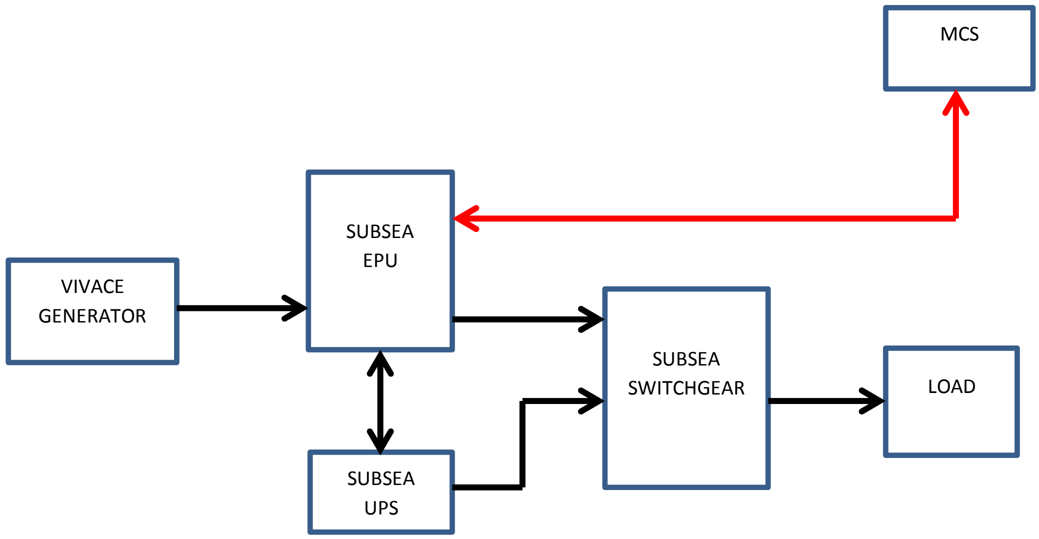


Figure 4.4: Proposed System Layout

1) Ocean current passed through the VIVACE cylinder, moving the cylinder up and down and generating electrical power through the side electromagnetic generator.

2) Generated power will go through subsea EPU where it will be conditioned and rectified into DC power.

3) Excess power will be stored in the subsea UPS for future usage.

4) The conditioned power will go into subsea switchgear. The subsea UPS also is linked to the switchgear.

5) From the subsea switchgear, the power can be supplied to the SPS load connected to it.

6) The control of the system will be merged with the CameronDC SPS Master Control System (MCS) to integrate the power supply system with the SPS.

4.7 Evaluation on the suitability of the proposed concept

The concept system needs to be evaluated to see whether it is suitable for its intended job, which is to supply electrical power to CameronDC SPS according to the required specification stated in the early stage.

4.7.1 Governing equation for power generation

In this system, the most important part is the generating the power. Therefore the governing equation will be focusing on the power generation of VIVACE system.

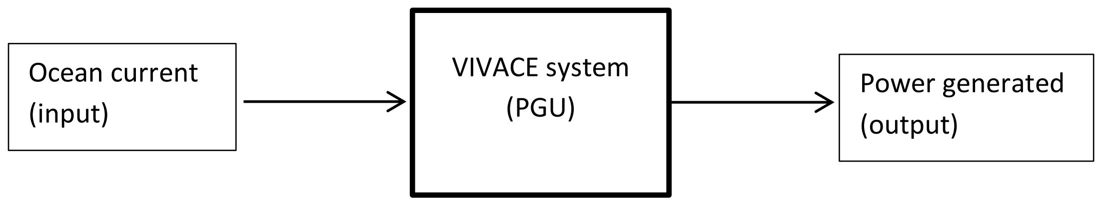


Figure 4.5: PGU operation

The corresponding equation will be:

$$P_{VIVACE} = \eta_{VIVACE} \frac{1}{2} \rho_w V^3 DL \tag{4.1}$$

Where:

P_{VIVACE} = Power harness by single cylinder VIVACE

η_{VIVACE} = efficiency of VIVACE

ρ_w = Seawater Density

D = Cylinder Diameter

L = Cylinder Length

The value of VIVACE efficiency can be obtained from the VIVACE test, which is approximately 0.22 (Bernitas). Seawater density is 1029kg/m3. From the design particular of VIVACE converter, a small scale VIVACE has cylinder diameter of 0.2m and length of 4m.

Considering several speed of current, the power generated by a single cylinder is drastically increase relative to the ocean current speed.

At V=0.5 m/s;

$$P_{VIVACE} = 0.22\ x\ \frac{1}{2}\ x\ 1029\ x\ 0.5^3\ x\ 0.2\ x\ 4 = 11.319W \qquad (4.2)$$

At V=1.0 m/s;

$$P_{VIVACE} = 0.22\ x\ \frac{1}{2}\ x\ 1029\ x\ 1.0^3\ x\ 0.2\ x\ 4 = 90.552W \qquad (4.3)$$

At V=1.5m/s;

$$P_{VIVACE} = 0.22\ x\ \frac{1}{2}\ x\ 1029\ x\ 1.5^3\ x\ 0.2\ x\ 4 = 305.613W \qquad (4.4)$$

At V=2.0m/s;

$$P_{VIVACE} = 0.22\ x\ \frac{1}{2}\ x\ 1029\ x\ 2.0^3\ x\ 0.2\ x\ 4 = 724.416W$$

(4.5)

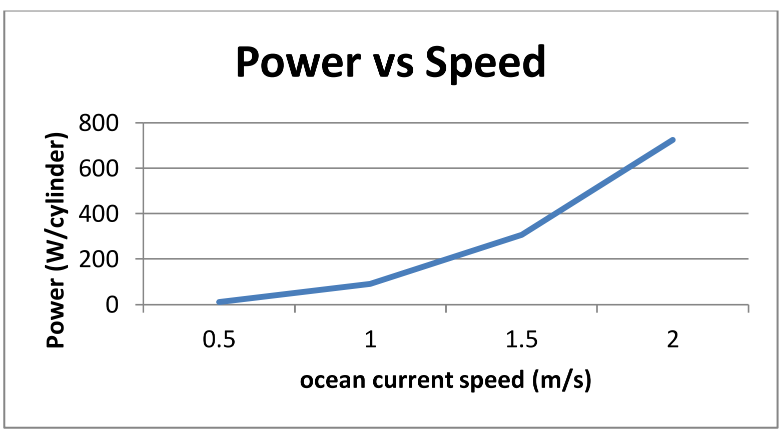


Figure 4.6: Power generated relative to the ocean current speed

Considering having the average current speed of 1.0 m/s, the proposed system will use 111 units of cylinder in order to achieve minimum power generation of 10kW. The amount of cylinder is still feasible. Furthermore, slight increase in speed will give additional power.

4.7.2 Comparison with patented system

This proposed system will be compared to a US patent; Electrical Power System for Subsea System (Karstad et al, 2009). This system is having its power generation on the topside. The power is supplied to the subsea facilities using submarine cable and utilized the transformers for long range transfer. The system can be compared at this point forward where it has its distribution units. It has an external pressure casing which contained the electrical power distribution units and other electrical element. In the proposed design, all the electrical equipment have their own pressure casing which making it easier to be arranged individually and still able to operate on the seabed level. The power generation is happening on seabed level therefore it did not need to have the transformers since the transfer distant is obviously shorter than from topside supply. The proposed system is basically have the same elements but differ in the arrangement and it should be suitable for the subsea application.

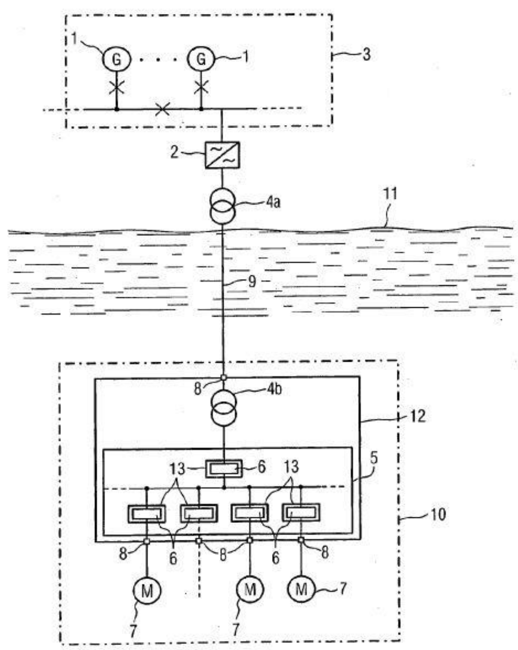


Figure 4.7: Electrical Power System for Subsea System (Karstad et al, 2009)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The objective of the project is to produce concept designs of alternative power generation for powering CameronDC SPS, producing the corresponding assembly drawing of the selected design concept and to evaluate the suitability of the proposed concept design. The proposed concept had been produced by mean of morphological approach which generates the concepts, evaluating it using weighted decision matrix scoring and taking the highest scoring concept as the proposed concept design. The assembly drawing of the proposed concept design is presented in this dissertation and also it is evaluated by studying its governing equation and to compare with patented system. The proposed concept system has its basic features to operate in seabed level to supply electrical power to SPS. The VIVACE system is suitable for this task since it has a very high power conversion ratio which allows good power generation from slow moving current. However this proposed design is still in the conceptual level. In order to fully operate, it is recommended for this concept to be taken to further level of design which is the embodiment design and detailed design. This project will help in expanding the concept of using VIVACE as the alternative power generation and expanding the idea of having alternative power generation on subsea level for other subsea application.

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