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Power Integrity Requirement of New Generation of ROV for Deep Sea Operation

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Abstract

Remotely operated vehicles (ROVs) system requires powerful vehicles to support the bollard thrust and tool power required for deepwater tasks. Evolving deeper waters, vehicle support for heavy-duty tasks demand, deepwater subsea construction, repair and maintenance require efficient ROV power pack to support these tasks. Typical work-class ROV systems provide maximum power levels ranging from 100 to 200 horsepower that produce impressive thrust in either vertical or horizontal directions. Problem associated with ROV power pack include inefficiencies in the power system designs that limit peak system performance thrust curves, inability of the hydraulic system to adjust to varying demands, environmental concern related to energy usage and ship husbandry. This paper address the design and development of a variable pressure power delivery and propulsion system that significantly increases overall system efficiency to maximize use of available power.

Key Words — ROV, electric power, reliability, deep water, offshore

Introduction

Environmental issue has been key driver to today technological decision. Deepwater marine operation has increased due to prohibitive nature of offshore activities in proximity to coastline. Deep water construction posed many challenges. This include the situation of water depth increases and subsequencial requirement for surface vessels size increase in order to support the equipment needed to reach the seabed. This makes the use and demand of ROVs imperative. Consequentially, the source of energy that meets these demands is increasingly becoming important. Energy space, size, and economic energy efficiency is tackled through increase ROV functionality with larger onboard power systems that provide more available thrust to support higher variety of tasks. Subsea equipment and hardware improvement has target effective equipment handling and design of a variable-pressure power delivery and propulsion system for completion of ROVs mission. All components of an ROV system should be rated to the maximum operating depth of the underwater environment anticipated, including safety factors. Pollution released from ROV devices have really been addressed, and the reality of environmental interaction makes it important for ROV system design to address ship husbandry problem. This paper discusses the potential of using alternative energy hybrid to power ROV system with hope to reduce challenge of air prolusion released to the atmosphere.ROV deep water operation find application in the following areas: FPSO, diving support, research vessel, drillship (Klages m. et al, 2002).

System Failure and risk based design requirement for ROV

In order to improve reliability of system, a generalized version and analytical expression for this important principle have also been formulated for multiple failure modes. It is argued that the traditional approach based on a risk matrix is suitable only for single failure modesscenarios. In the case of multiple failure modes (scenarios), the individual risks should be aggregated and compared with the maximum tolerable risk. Risk-based design is important in order to minimize the probability of system failure below a maximal acceptable level at a minimum total cost (the sum of the cost for building the system and the risk of failure).

Today, design shift towards knowledge intensive product, risk based design is believed to be key elements for enhancement of industrial competitiveness. The use of risk based design, operation and regulation open door to innovation and radical novel and inventive, and cost effective design solution. Risk based approach for ROV follow well established quantitative risk analysis used in offshore industries. The key to successful use of risk based design require advance tool to determine the risks involved and to quantify the effects of risk preventing/reducing measures as well as to develop (evaluation criteria to judge their cost effectiveness. ROV operating capabilities requirement that can be investigated is under risk based design are:

i. Standardized intervention ports for all subsea with any available ROV.
ii. Visible mechanical indicator or redundant telemetry channel
iii. ROV testing requirements
iv. Electrical power requirement

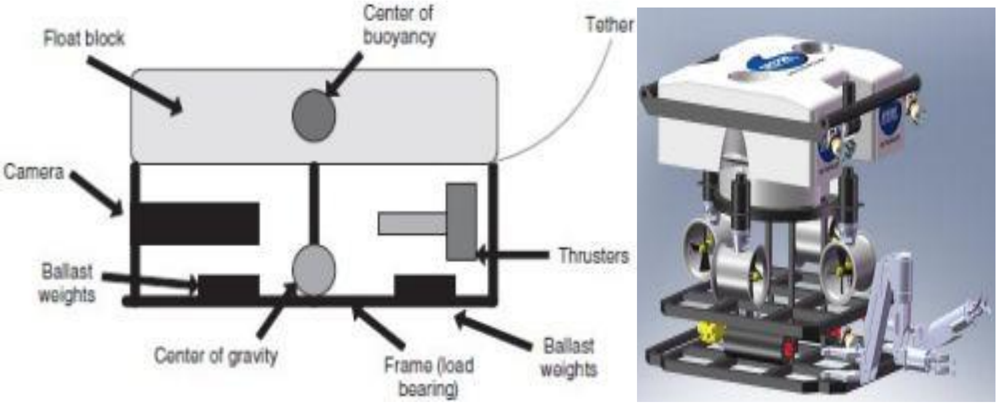
General requirements - refer to SOLAS requirements, Part D, Chapter II-1 - outlines requirements for Ship construction sub-division and stability, machinery and electrical installations

ROV System and subsystem

The ROV system is one of the simplest robotic designs, where complex assignments can be accomplished with a variety of closed-loop aids to navigation. ROV system has its immovable locomotive part and counterparts that are capable to move under its own power. The power of locomotion has ability to navigate the robot, with levels of autonomy to achieve defined mission. Remote operated vehicle (ROV) are built with secondary control of the subsea blowout prevent or (BOP) stack, and most provide other tertiary control systems as well. The ROV intervention capability is limited on some subsea BOP stacks while others have the ability to control multiple functions. ROV intervention capabilities for secondary control of all subsea BOP stacks, including the ability to close all shears and pipe rams, close the choke and kill valves. Deep water operation requires larger component wall thicknesses are required for the air-filled spaces (pressure-resistant housings) on the vehicle. This increased wall thickness results in an increased vehicle weight, which requires a larger floatation system to counter the additional weight. This causes an increase in drag due to a larger cross-section, which requires more power, hence large cable to become larger.

Today design culture is embracing the open source computer-based control models that allow users to design their own navigation and control matrix. This concept allows development of new techniques; define by the user's imagination. Open source platform take the control of the development of navigation capabilities including the mission from the hands of the design engineer (who may or may not understand the user's needs) into the hands of the end user (who does understand the needs). Cost efficient design of the systems with the user in mind is critical to the success of the ROV and the mission. Saving weight is also key cost-effective design and operation.

Figure 2.2.4 a shows components of ROV that must be incorporated in the design spiral of the electrical requirement [1], [2], [3]. Figure 2.2.4 b shows H-ROV.



a. b.

Figure 2.2. 1: ROV parts

The vehicle power system can be conveniently divided into transmission and distribution systems, which are described in sequence below. The transmission and distribution system prototyped mode is encouraged to designed, built, and tested before scale up and deployment. **ROV subsystem includes** [3]**:**

i. **lighting**
ii. **cameras**
iii. **sensors and manipulators**
iv. **electrical**

Recent year have seen development of third generation ROV with Hybrid ROV that utilize hybrid design, one of such design is H-ROV which was developed in collaboration with Data Response Kongsberg by Sperre AS. H-ROV is built with an advanced propulsion system, auto-tracking, and an ingenious multiple control tool platforms for subsea DP and auto-traction operations. The redundancy system can benefit from robust electrical system design.

UMT ROV – STEALTH 2

The Stealth Remotely Operated Vehicle by Shark Marine Technologies Inc., is versatile ROVs on the market today. Small in size and portable with many features and capabilities. The Stealth ROV is packaged with plug and play ready for such options as scanning sonar, manipulator arm, sub-bottom profiler, and total positioning system. The size and weight (45kg) of this ROV system allows for operation from even small boats or inflatable's. The Stealth2 computer controller with its daylight viewable, graphical interface allows completely automated control of the ROV functions. Settings are provided for auto-depth, auto-heading, auto altitude and vertical trim as well as for monitoring the ROVs internal environment. The computer controller may also be used for processing other Windows based options such as sonar or vehicle tracking. On-screen displays simplify navigation and provide valuable information during video playback as well as efficient high quality recordings of video, jpg and .mpeg. Figure 2.2.5 shows UMT Stealth ROV.

Figure 2.2. 2: UMT Stealth ROV

Table 2.2. 1: Specifications

Vehicle Dimension	**:**	**30"Lx22"Wx18.5" inc. handle**
Vehicle weight	:	90 lbs. (40 kg)
Controller dimension	:	21"Wx18"Dx9"H
Controller weight	:	44 lb. (20 Kg) (Including Hand Control)
Hand Control Dimension	:	7.5"Wx7.5"Dx3"H
Hand Control Weight	:	4 lbs. (1.8 kg)
Hand Control cable length	:	15 ft standard (longer optional
Neutral umbilical description	:	Urethane jacket with TPR floatation jacket, 1000 lbs minimum breaking load
Neutral umbilical size	:	0.53" diameter (12.7 mm)

Neutral umbilical length	:	500 ft standard (up to 2000 ft optional)
Neutral umbilical Weight	:	52 lbs per 500 ft (20kg per 150) Dry weight
Horizontal Thrusters		2 each, 1/3 Horsepower
Vertical Thrusters	:	2 each, 1/3 Horsepower
Lighting	:	2 each 150 Watt quartz- Variable control
Camera	:	High resolution colour 450 TV line (Others optional)
Camera motion	:	180 degree viewable (pan optional)
On screen display	:	Depth, Heading date, time, title (Others optional)
Scanning Sonar	:	Pre-wired for plug & play (Sonar optional)
Depth rating	:	1000 feet (300m)

The stealth can also fulfill other mission with manipulator arms, cutting arms, scaling lasers, various cameras; including zoom features or extreme low light, tracking systems, sonars; including multiple receiver units and sub-bottom profilers, gradiometers, magnetometers, recovery tools, cable reel systems and more. The stealth has application in different underwater operations from inspection services, to search and recovery, to environmental studies, to archaeological investigations. Vehicles are presently in use the world round by various navies, marine institutes, logging companies, underwater recovery units, commercial dive operations and more. Table 2.2.3 shows specification of the stealth.

New Generation of ROV for deep water operation challenge electrical power requirement

ROV power performance and efficiency depends on capability to effectively lifting heavy objects, pushing large equipment items into position, and acting as a supply for high-powered tooling at minimum cost, space and time. Increased input power of ROV system means increased electrical current capacity requirements for the umbilical/tether system and increased motor, pump, and thruster sizes. As well as sub sequential system changes to support these primary size/capacity increases, use of more copper in the umbilical that requires more steel armor on the cable because weight of the conductors is entirely parasitic. The main components **of the power system include [4] (See Figure 2.2.6):**

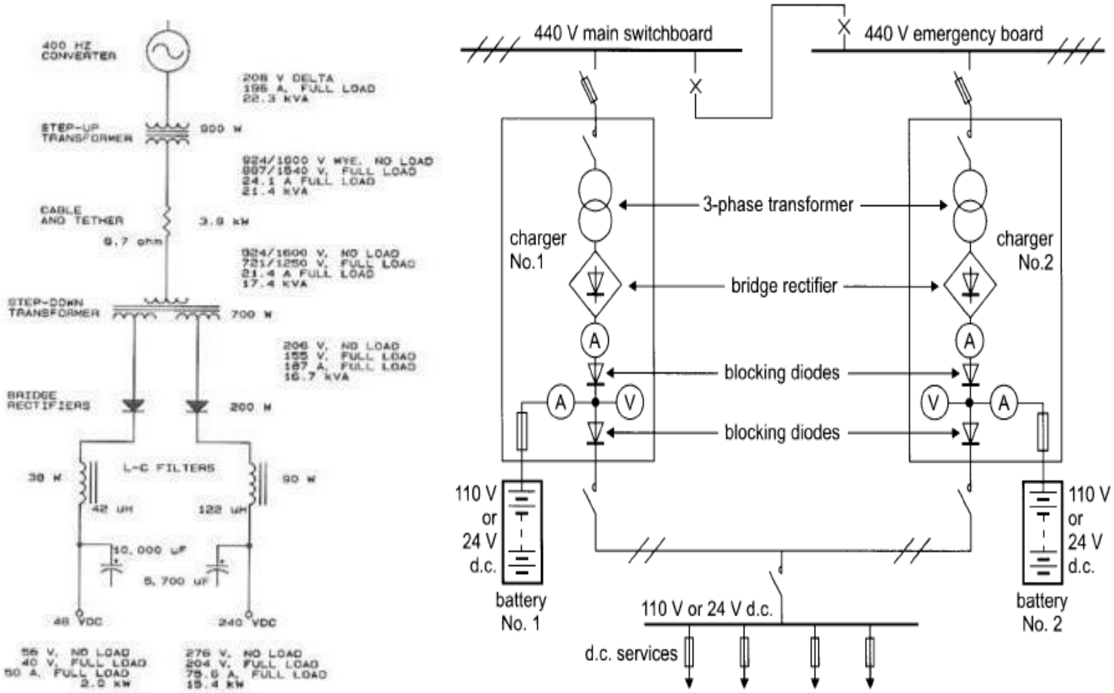
i. **Power source**
ii. **the tether**
iii. **data**

iv. **the connectors**

The ROV is simply a delivery platform for transporting the sensor package to the work location. The Human-Robot Interface (the intuitive interaction protocol between the human operator and the robotic vehicle) is still in its infancy; However, sensors are still outstretching the human's ability to interpret this data fast enough to react to the feedback. Beside this deep sea operation is imposing more requirements for the power design, rating and application of new generation of ROV. The majority of the company’s assignments have involved the development of tailor-made solutions to solve specific problems in subsea operations for their customers.

Power Distribution System

To satisfy environmental problem, recent design also focus on minimized acoustic emissions, fiber optic telemetry system, and full integration of vehicle, navigation, and science sensor data streams. One of the evolving ROV technologies is the design pioneer by Mbari, where the ROV is designed to operate up to 4000 m depth rating, 100 kg payload with +/-35 kg variable buoyancy adjustment, precision 4 degree-of-freedom vehicle control. Operational features include a quick-change payload toolsled, and extensive onboard fault detection and isolation capability.



a,   b.

Figure 2.2. 3: One – line diagram of power transmission

The ROV electrical power system to deliver and manage 15 kW of DC electrical power, primarily to meet the vehicle propulsion goals of 1.5 knot free speed and 0.75 knot full depth transit (i.e., with cable drag). The electrical load capability includes 3.7 kW (mechanical output) brushless DC permanent magnet motors. Distribution voltage selection is based on vehicle performance and personnel safety issues. Traditionally ROV vehicle operate mostly at 120V, due to power requirement the industry is adopting 270 and 240 VDC full wave rectification of 120/208 three phase AC for manned submersible, this in line with aircraft power distribution, after apparent that the 5 kW demanded by the largest loads would require large and heavy switches, connectors, and wiring at 120 V. emerging practice for 270 VDC aircraft power distribution, and with. 48 VDC is presently the highest industry standard voltage that can be considered "low voltage" for safety purposes. However, due to deep sea operation environment future ROV will require all electric power operation with high voltage demand. Such system will require the use of SCADA and Distributed Computer System for the vehicle data management system.

The power distribution system include the DC busses, power switches, ground fault detection system, and motor regeneration control system. Mbarry system deisgn employ distribution and control system design where 15 kW of 240 VDC power and 2 kW of 48 VDC power on each of the A and B busses that have synchronization capability and leaves room for future upgrades to the transmission system as well. The ability to detect ground fault conditions on any circuit passing through seawater; the ability to switch off and fully isolate any faulted load circuit; and minimization of personnel exposure to 240 VDC circuits and wiring (See Figure 2.2.6 a). This diagram shows the values for voltage, current, kVA, and power loss throughout the system, at no load and full load operating points. The system end-to-end load factor or ratio of power delivered to power lost in transmission. This value can be determined after a survey of load analysis requirements, as a tradeoff between voltage regulation and power delivery capability. Figure 2.2.6 b. Typical uninterrupted power system for 480 volt system.

The standard for work class ROVs is to use electrical power, from the umbilical, which is converted to hydraulic power. This requires an inefficient process that requires a lot of electric power. Electric thrusters could increase the reliability of an individual ROV (See Figure 2.2.7).

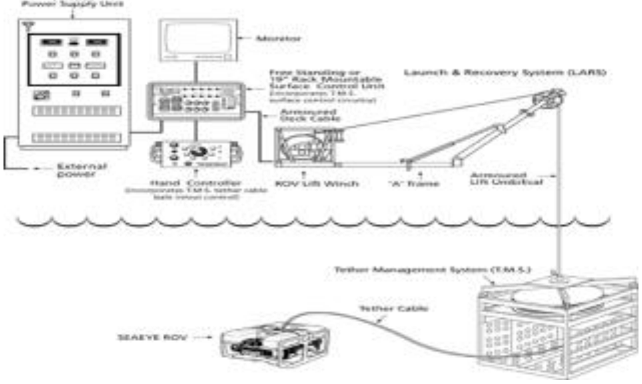


Figure 2.2. 4: ROV with umbilical delivery system

The electric ROVs have fewer moving parts so they should be easier and cheaper to maintain over the long term. For ultra-deepwater operation efficient electric could provide more capability than current hydraulic ROVs cannot efficiently access. Traditionally, deepwater ROV designs were beefed-up versions of shallow water designs. What is needed now is change in technology that will generate all-electric ROVs with the power and versatility of the current fleet and the added ability to operate in ultra-deepwater [5], [6]. An all-electric remotely operated vehicle (ROV) is being popular for deep water operation. They have high reliability, layout flexibility, load diversity and economic part load running, easy control and low noise and vibration. Early ROV designs of every description relied on established electronic technology. In fact, the first ROV, the US Navy's CURV, used to recover a hydrogen bomb off the coast of Spain in the 1950s was all electric. One problems with the all-electric design were that as ROVs got larger, so is the thrusters. An electric-thruster ROV is more efficient.

Another primary reason all-electric ROVs will be used in ultra-deepwater has to do with the umbilical. The umbilical connects the ROV cage to the winch and control equipment on the surface. The umbilical provides power to the unit and communications back and forth between the operator and the ROV. The umbilical also hoists and lowers the ROV and its cage. To handle this strain, and protect the power and communication lines inside, the umbilical is armored by a steel coating. This coating is protective, but also very heavy. The larger the diameter of the umbilical, the heavier the armor. At a certain depth, the size umbilical needed to transmit power to a hydraulic work class ROV would require an umbilical that is too heavy to support its own weight. The steel would no longer do the job. That require lightweight alloy such as titanium, or to Kevlar. Titanium would work, but is prohibitively expensive, as is Kevlar. Figure 2.2.8 shows a typical system for All electric system.

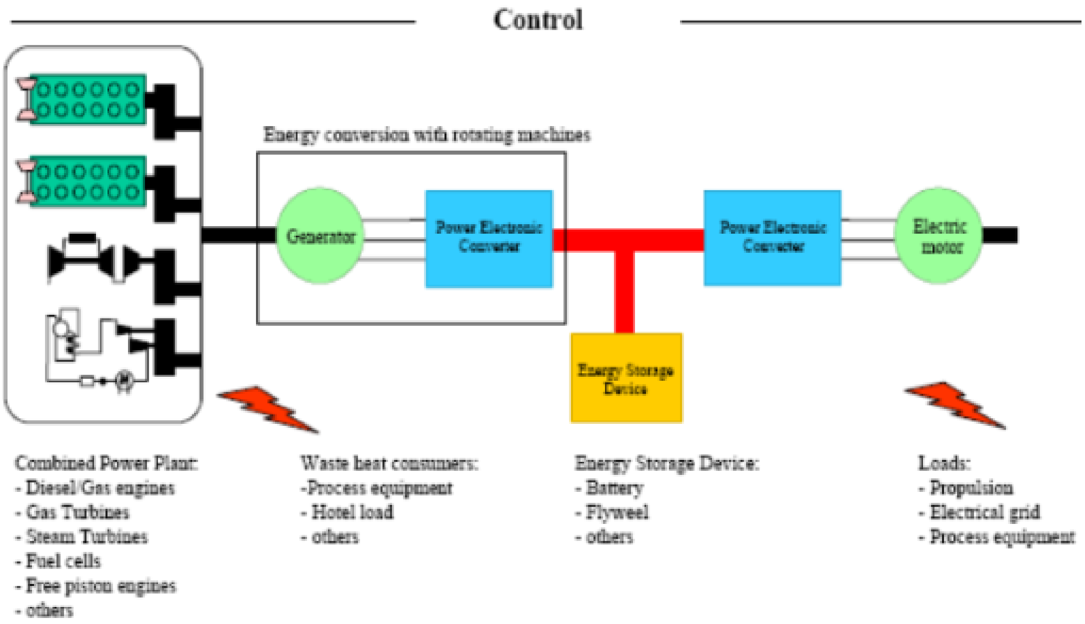


Figure 2.2. 5: All electric system

The university of Alaska in collaboration with industry are developing a new ROV system capable of rapid accost effective scientific response to dynamic underwater events such as hydrothermal diking, catastrophic shelf slumping, phytos plankton blooms and other transient phenomena. The general schematic includes (See Figure 2.2.9):

i. surface control console with pilot monitors and control
ii. remote science and monitoring stations, and deck cabl
iii. winch, CTD cable and depressor weight
iv. vehicle tether and vehicle
v. scientific payload

Safety for 240 V circuits are restricted to high power loads that are not frequently opened, and the circuits appear in only a limited number of wiring junction boxes. Both the 240 V and the 48 V systems is required to be fully isolated from frame ground, and ground fault monitor circuits to warn if the impedance to ground falls low enough to cause a hazardous condition. It is therefore essential that personnel are trained in safe working practices for these voltages. This will mean a considerable increase in the electrical content of all training.

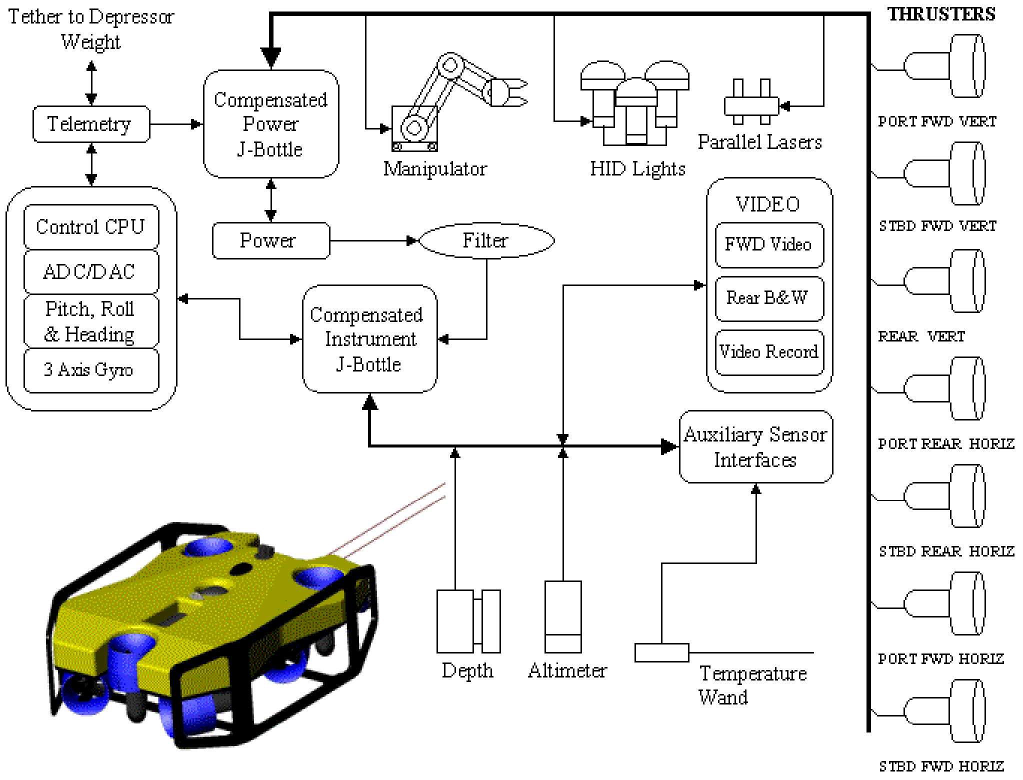


Figure 2.2. 6: ROV Distribution system

Power Source requirement

Electrical power transmission is an important factor in ROV system design due to their effect upon component weights, electrical noise propagation and safety considerations. The ROV power system design involves series of compromises and trade-off of cost, safety, and needed performance. The power system design reflects the overall vehicle. The design involve an iterative process that starts with goals for vehicle payload, operating depth, speed, support ship size, and vehicle and cable technologies. The payload, depth, and speed are derived from science requirements. , the size is defined, and most technology choices are chosen based on common science and acceptable flexibility for required schedule and resource constraints. Payload and depth requirements and propulsion system are deduced from vehicle size and frontal area.

Consideration for choice between AC and DC is another challenge in the power design. Direct current (DC) allows for lower cost and weight of tether components; Since inductance noise is minimal, it allows for less shielding of conductors in close proximity to the power line as well as weight considerations for portability, and the expense of power transmission devices. Alternating current (AC) allows longer transmission distances than that available to DC while using smaller conductors as smaller systems use only DC as their power source. Submersible systems attempting to escape a hazardous bottom condition have been known to lose power at critical moments while the vessel is making power-draining repositioning thrusts on its engines. This can cause entanglement of the vehicle. Submersible maneuvering power can be separately provided. With the advent of the lightweight micro-generators for use with small ROVs, the portability of the ROV system is significantly enhanced. Battery/inverter combination for systems AC and DC power also contribute to light weight effort. Emergency system power source capable of uninterrupted power to the system at its maximum sustained current draw for the length of the anticipated operation is also a necessity for design requirement. On larger ROV systems, AC power is used for the umbilical due to its long power transmission distances, which are not seen by the smaller systems. AC power in close proximity to video conductors could cause electrical noise to propagate due to EMF (electromotive force) conditions. Larger work-class systems require the use AC power transmission from the surface down the umbilical to the cage (the umbilical normally uses fiber-optic transmission, lowering the EMF noise through the video) since the umbilical does not require neutral buoyancy. At the cage, the AC power is then rectified to DC to run the submersible through the neutrally buoyant tether that runs between the cage and vehicle. Uninterrupted power supply system is important to sustain power requirement of ROV and its recovery system. Potential energy source for ROV are:

i. Fuel Engines combustion engine could operate in form of:
    a) Internal combustion engines – Diesel engine

    b) External combustion engine – Braytoncycle (gas turbine) engines, Steam engine
- ii. Batteries and Fuel Cells – Electrochemical processes at work
    - a) Canonical battery technologies
    - b) Fuel cell characteristics
- iii. Others : Nuclear power sources, renewable energy,
- iv. emissions, green manufacturing, primary batteries, generators

Size and weight of power system matter in the design and estimation of resistance of marine vehicles, Figure 2.2.10 gives size standing information of power source option.

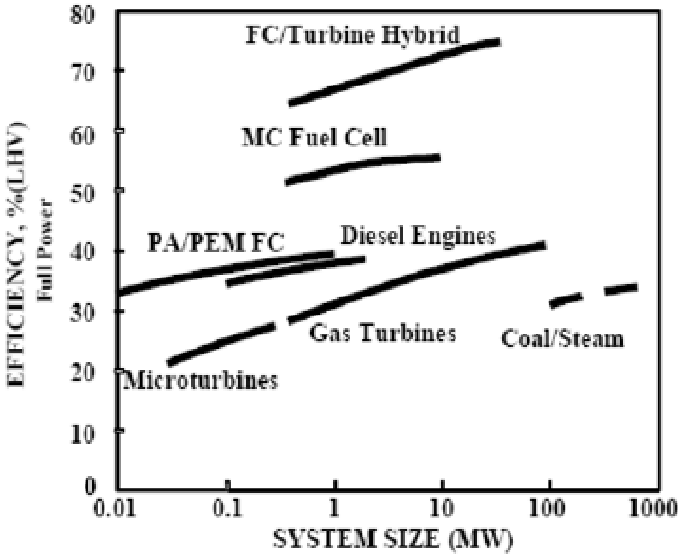


Figure 2.2. 7: Power efficiency

<u>Requirement of power systems for marine applications</u> include:

- i. Shows typical continuous UPS DC supported supply system
- ii. Essential DC services supplied from 440V through charger 1 - continuously in trickle charges
- iii. During power loss, battery should be able to maintains transitional supply while emergency generator restores power to emergency board & charger 2
- iv. Either battery is available for few hours if both generators are unavailable
- v. Some critical emergency lights should have internal battery supported UPS i.e. battery charge continuously during non emergency conditions
- vi. Main Supply of power energy source must be carried on board; has to last days, months, years.
- vii. Weight and volume constraints may be significantly reduced compared to terrestrial and esp. aeronautical applications.

viii. Reliability and safety critical due to ocean environment.
ix. Capital cost, operating costs, life cycle analysis, emissions are significant in design, due to large scale.

Understanding of the science of energy is also important requirement. Energy can be produced through electrochemical, combustion, electromagnetic, heat, mechanical system alternative or their combination. Electrochemical process involve engines convert chemical energy into heat energy or mechanical or kinetic energy where 1 MegaJoule is: 1 kN force applied over 1 km;1 Kelvin heating for 1000 kg air;1 Kelvin heating for 240 kg water; and 10 Amperes flowing for 1000 seconds at 100 Volts. Table 2 shows various heating content for available energy option for ROV.

Table 2.2. 2Energy source fuel heat content

Fuel	Heat content(MJ/KG)
Gasoline(C_8H_{15})	45
Diesel($C_{13}H_{23}$)	42
Propane(C_3H_8)	48
Hydrogen(H_2)	130
Ethanol(C_2H_5OH)	28

$C_8H_{15}+47O_2 \rightarrow 32CO_2$+other product

Gas turbines are preferable due to extremely high power density, and the high thermal energy content of traditional fuels. Li-based batteries now available at ~0.65MJ/kg (180kWh/kg); gold standard in consumer electronics and in autonomous marine vehicles. Fuel cells are still power- sparse and costly for most mobile applications, but continue to be developed. They are more suitable for power generation plants in remote locations. Example of specification of gas turbine engine that can be used for ROV is LM2500 Specifications:

i. “ Output: 33,600 shaft horsepower (shp)
ii. Specific Fuel Consumption: 0.373 lbs/shp-hr
iii. Thermal Efficiency: 37%
iv. Heat Rate: 6,860 Btu/shp-hr
v. Exhaust Gas Flow: 155 lbs/sec
vi. Exhaust Gas Temperature: 1,051°F
vii. Weight: 10,300 lbs
viii. Length: 6,52 meters (m)
ix. Height: 2.04 m
x. Average performance, 60 hertz, 59°F, sea level, 60%

xi. relative humidity, no inlet/exhaust losses, liquid fuel,
xii. LHV=18,400 Btu/lb ”

Energy storage technology remains a challenge for the use of alternative energy for ROV.An example of a simple battery would be one in which zinc and carbon are used as the electrodes, while a dilute acid, such as sulfuric acid (dilute), acts as the electrolyte. The acid dissolves the zinc and causes zinc ions to leave the electrode. Each zinc ion which enters the electrolyte leaves two electrons on the zinc plate. The carbon electrode also dissolves but at a slower rate. The result is a difference in potential between the two electrodes.
The Dry cell is relatively inexpensive and quite portable. The anode consists of a Zinc is placed in contact with a moist paste of $ZnCl_2$ and NH_4Cl. A carbon rod surrounded by MnO_2 and filler is the cathode. The cell reactions vary with the rate of discharge. Lead acid cell are electrodes of lead and lead dioxide, dipping into concentrated sulfuric acid Nominal discharge rate C is capacity of battery in Ah, divided by one hour (typical). Lithium primary cells can reach 2.90 MJ/l. Table 4 and Figure 2.2.11 show performance battery.

$$P_b -> Pb^{2+} + 2^{e-} \tag{1}$$

(Oxidixed) or

$$P_b + So4^{e-} + 2^{e-} -> P_b So4 + 2^{e-} \tag{2}$$

Gatherin electron at the positive electrode

$$Pb^{4+} + 2^{e-} -> Pb^{2+} \tag{3}$$

(reduced) or

$$Pb^{2+} + So_4{}^{2-} + 4h^{+} - 4h^{+} -> 2Pbso_4 \ + 2h_2o \tag{4}$$

Total chemistry of the lead acid

$$Pb^{2+} + So_2{}^{2-} + 2so_4{}^{2+} + 4^{+} -> 2Pbso_4 + 2h_2o \tag{5}$$

Typical Fuel cell employ electrochemical conversion work likes like a battery, but the fuel cell is defined as having a continuous supply of fuel.

At anode, electrons are released:

$$2h_2 -> 4h^{+} + 2^{e-} \tag{6}$$

At cathode, electrons are absorbed:

$$0_2 -> 4e^{-} + 4h_2o \tag{7}$$

Fuel cell have high sensitivity to impurities: e.g., PEM FC is permanently poisoned by 1ppb sulfide. Weight cost of storage of H2 in metal hydrides is 66:1; as compressed gas: 16:1 while oxidant storage: as low as 0.25:1. Reformation of H2 from other fuels is complex and weight inefficient: e.g., Genesis 20L Reformer supplies H2 at ~ 0.05 kW/kg. Fuel cell also have characteristics to change load rapidly.

Power Transmission Conversion and Transformation Requirement

The power transmission system include the shipboard power source, step-up / step-down transformers, vehicle cable and tether, and power conversion equipment required to produce DC distribution power aboard the ROV. Once vehicle size, depth, and speed are determined, the main cable, power transmission system, and propulsion system co-designed can be taken through iterative process. AC and DC power distribution choice and routing is very important in the design of ROV. Table 2.2.5 and Figure 2.2.11 shows typical figure for battery performance.

Table 2.2. 3: Comparison of battery performance

	Energy density (MJ/Kg, MJ/i)	Mem or Y effect	Maximum current	Recharge efficiency	Self discharge %/min at 293k
Lead Acid	014, 0.36	No	20c	0.8-0.94	
Ni Cd	0.24, 0.72	Yes	3c	0.7-0.85	25
NiM H	0.29, 1.08	Yes	0.6c		>20
Li Ion	0.43-072, 1.03-1.37	No	2c		12

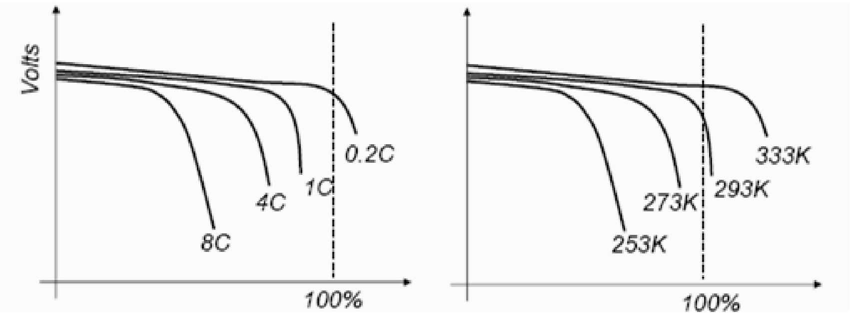


Figure 2.2. 8: Battery performance

Power conversion for the system involves the use of solid state rectifier (diode, SCR). These converters are also example of game changer in the decision analysis for use of AC/DC and hydraulic system. But they also require protection of large semiconductors, e.g. thyristors, which can additionally be destroyed by a fast rate-of-change of. Voltage and current caused by rapid switching. To suppress a rapid overvoltage rise (dv/dt) across a thyristor an R-C snubber circuit is used. Its action is based on the fact that voltage cannot change instantaneously across a capacitor. The series resistor limits the corresponding current surge through the capacitor while it is limiting the voltage across the thyristor. Significant heat will be produced by the resistor which, in some applications, is directly cooled by water jacket. An in-line inductive effect will limit the rate-of-change of current (di/dt) through the thyristor. (E. Mellinger, 1986). Special fast-acting Line fuses may be used as back-up over current protection for the thyristors. Circuit protection for the electric propulsion units (including excitation and harmonic filters) principally employs co-ordinate protective relays.

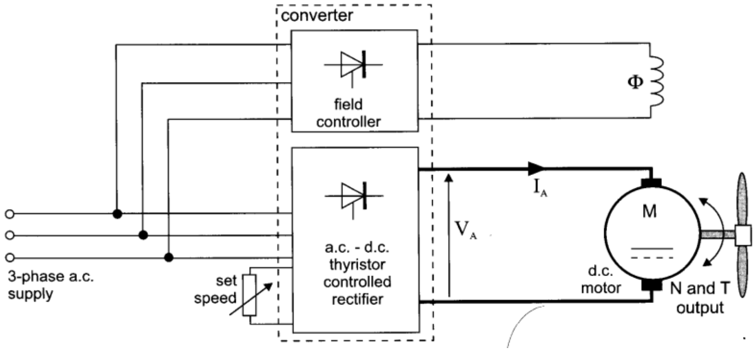


Figure 2.2. 9: a) SCR operation

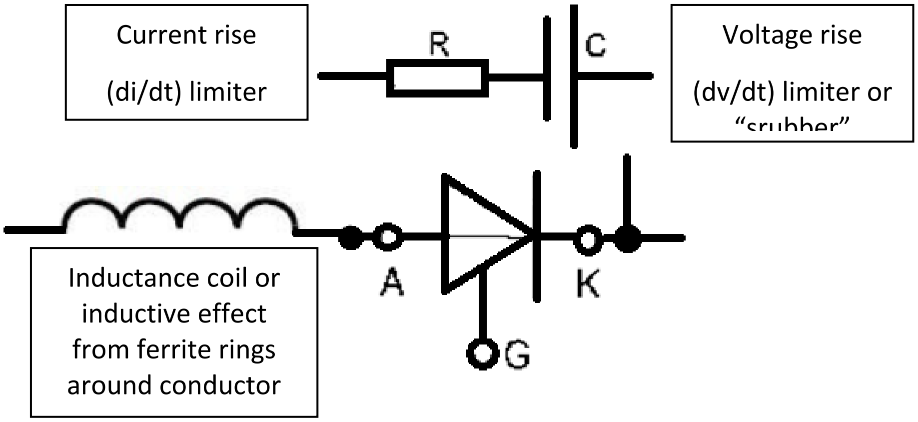


Figure 2.2. 10: b) SCR protection

The parallel of a conventional AC relay with solid state devices, in this case Insulated Gate Bipolar Transistors (IGBTs) provide arcless make and break for the DC current, while the relay contacts carry the steady state load with only a few watts loss. Logic on the card sequences, the switching events and responds to overloads, and a shunt resistor and A/D converter allow current to be sensed and reported (See Figure 2.2.12 a and b show SCR system and protection [9], [14]. Power transformation include the use of step-up and step-down transformers with use of material that target less losses - no load (iron) and full load (copper) losses. The transformation also depends on the connection (delta, wye, delta) arrangement of input, cable, and output circuits that can minimize the current waveform crest factor presented to the converter, so that each transformer has a delta winding for harmonic current control and a wye high voltage winding for minimum insulation stress. The vehicle step-down transformer contributes significantly to vehicle mass and volume budgets, and of scientific importance, to the vehicle acoustic signature as well. Figure 2.2.14 a and b show power transformer and converter system.

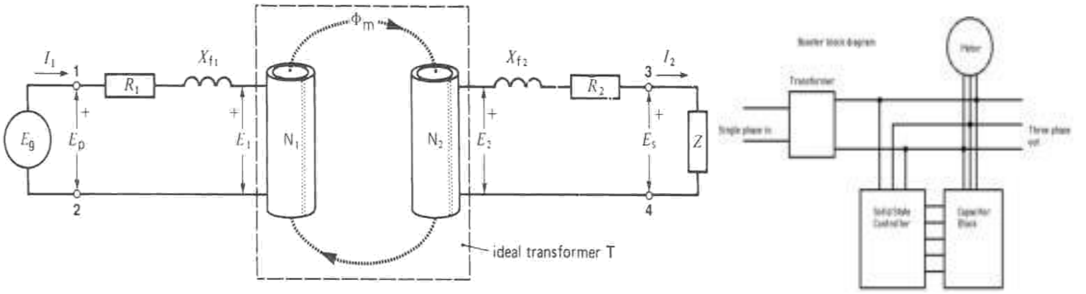


Figure 2.2. 11: a) Power transformer, b) Power converter

Transformer noise is largely due to core magnetostriction, and thus is present, and in fact maximum, when motors are off, loads are small, and input voltage is high, as during "quiet sub" operation. Reductions of transformer mass and volume are desirable, but these increase core flux level and winding current density, and thus increase both noise and thermal output. The keys to a small, light, quiet transformer thus became getting the waste heat out while keeping the noise in. This in turn meant breaking the acoustic path to seawater with an absorptive layer or a sharp discontinuity in acoustic impedance, while preserving high thermal conductivity. By acoustically isolate the transformer using a gaseous vapor barrier, while using the vapor's latent heat of evaporation to carry the transformer's heat away. The choice of liquid is obviously critical since it must have high dielectric strength in both phases, high latent heat, and material compatibility, not to mention low toxicity, environmental correctness, and low cost. Figure 2.2.15 show the tether cross section and the cable sizing requirement (A. Kelley, 1992).

$$\frac{E_1}{E_2} = \frac{N_2}{N_1} \qquad (8)$$

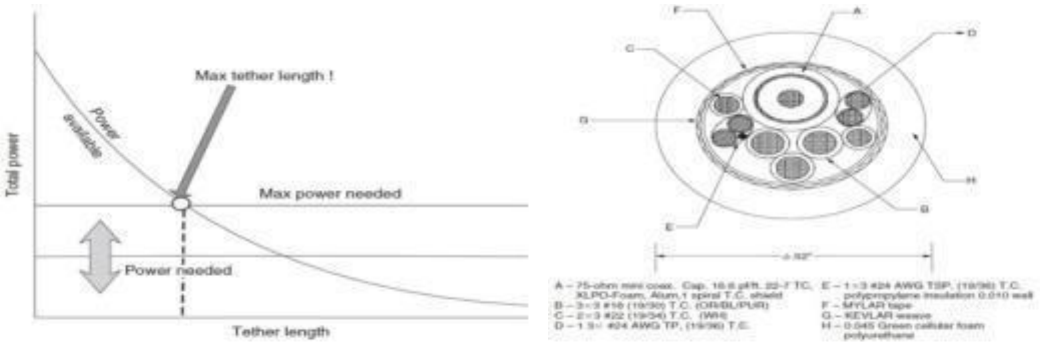


Figure 2.2. 12: a) Tether, b) Cable sizing

Motor and Thruster Control System

The main are connected the propeller for horizontal an vertical thrust. Today, robust motor system comes which thyristor power management system that have control capability for maneuvering propulsion, trusting. On older analog systems, a simple rheostat controls the variable power to the electric motors, while newer digital controls and SCR are necessary for more advanced ROV movements. Figure 2.2.16 a and b show motor power requirement and torque speed characteristics.

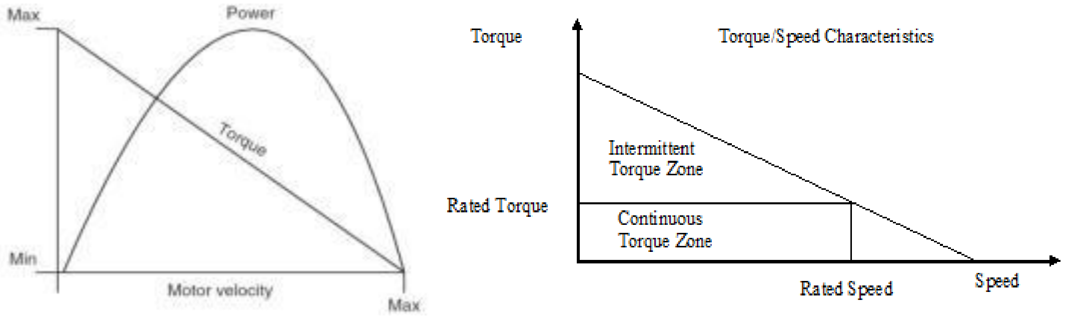


Figure 2.2. 13: a) Motor Power, b) Torque speed characteristics

$$S_{input} = \sqrt{3}.V_{line}.I_{Line}.....VA \qquad (9)$$

$$\eta = \frac{p_{shaft}}{p_{input}} = \frac{p_o}{p_{in}} \qquad (10)$$

$$P_f = \frac{p_{input}}{S_{input}} \qquad (11)$$

Regeneration control reflect behavior of motors like generators during braking, this lead too high frequency voltage. High bandwidth thrust control, necessary for precision vehicle control, is expected to require frequent and repetitive motor braking, in order to minimize thruster response time.

Power Connector (Cable and Tether)

Umbilical refer to the cable linking the surface to the cage or tether management system (TMS). Tether is the cable from the TMS to the submersible. Any combination of electrical junctions is possible in order to achieve power transmission and/or data relay. AC power may be transmitted from the surface through the umbilical to the cage, where it is then changed to DC to power the submersible's thrusters and electronics. Further, video and data may be transmitted from the surface to the cage via fiber-optics (to lessen the noise due to AC power transmission), then changed to copper for the portion from the cage to the submersible, thus eliminating the AC noise problem. The umbilical/tether also should have strength member allowing for higher tensile strength of cable structure and Protective outer jacket for tear and abrasion resistance. The tether length is critical in determining the power available for use at the vehicle following law of resistance and Ohm law. The power available to the vehicle must be sufficient to operate all of the electrical equipment on the submersible.The maximum tether length for a given power requirement is a function of the size of the conductor, the voltage, and the resistance [7]. Standard copper wire requirement is shown in Table 2.2.6.

$$R = Ro\, l / A \qquad (12)$$

$$V = IR \qquad (13)$$

Table 2.2. 4: Standard copper wire gauge resistance over nominal lengths (Deep sea power and light)

Wire gauge	Ohm/1000ft (approx)
20	10
18	6
16	4
14	2.5
12	1.5

Salt water is highly conductive, causing any exposed electrical component submerged in salt water to short to ground. The result is the 'Ubiquitous ground fault'. The purpose of an underwater connector is to conduct needed electrical currents through the connector while at the same time squeezing the water path and sealing the connection to lower the risk of electrical leakage to ground. The underwater connector is lined with synthetic rubber that blocks the ingress path of water while allowing a positive electrical connection. Connectors sometimes experience cathodic delamination, causing rubber peeling and flaking from the connector walls. connector maintenance[8]:

i. Use small amounts of silicone grease to lubricate the connector, thus allowing easier slide on and off. Using too much grease, a widespread problem, can interfere with sealing.
ii. Always pull the connector by its body instead of its tail (cable), since the wire splice is located in the connection. Pulling on the tail could part the solder joint and ruin the electrical continuity within the connector.
iii. Keep the connectors as clean as possible through regularly scheduled maintenance tasks that include cleaning the contacts and lubricating the rubber lining.
iv. Spray the connector body with silicone spray to keep the housing from drying out, which could result in flaking and rubber degradation.

The connector materials must be able to withstand the environmental conditions without degradation. The physical size of the connector, its weight, ease of use (and appropriateness for the application), durability, submergence (depth) rating, field reparability, etc. should all be assessed. Other important requirement for cables include insulation spacing and right-of-way, operating capacitance and charging current, transmitted power, reliability and installation costs. Design element of cable includes metallic covering, outer coverings and corrosion protection, losses and temperature factors.

Power safety Stabilization Requirement

Power safety and harmonic stabilization are very important part of high demand regime of ROV vehicles. For the typical distribution arrangement earlier mentioned, power stabilization can be provided by four rectifier bridges actually contain Silicon Controlled Rectifiers (SCRs) which are fired by zero-crossing circuits and operate in on/off mode as electronic circuit breakers for their associated power busses. Fast fuses at each rectifier input protect against SCR or other catastrophic failure. Each rectifier bridge is followed by an L-C filter that reduces output ripple voltage, and reduces harmonic currents drawn from the power transmission system. Positive Temperature Coefficient (PTC) thermistors are used as constant-power capacitor bleeders

Two design features that increase the operational availability of the vehicle power transmission system are redundancy and fault tolerance. Redundancy incorporates the use of dual power busses for each distribution voltage. Thrusters are arranged so that failure of one 240 V bus leaves one vertical plus two horizontal thrusters available (lateral or fore-aft), which allows yaw control, translation, and vertical motion. The critical loads such as the main computer draw power from both A and B busses through diode-OR circuits. Fault tolerance is achieved through coordinated overload protection plus the ability to selectively isolate loads using switches in the distribution system. Here fuse and circuit breaker current-time characteristics are selected so that the over current device closest to the faulted load trips first, allowing operation on the non-faulted part of the system to resume with minimal interruption. The circuit breakers also function as controlled switches, and are commanded to disconnect loads when a ground fault is sensed on the associated supply bus, again allowing operations to continue.

Grounding implies an intentional electrical connection to a reference conducting body, with specific array of interconnected electrical conductors. Grounding systems should be serviced as needed to ensure continued compliance with electrical and safety codes, and to maintain overall reliability of the facility electrical system. All vehicle electrical systems are fully isolated from frame (seawater) ground. The insulation resistance must be continuously monitored for reasons of safety, and also to provide early warning of seawater intrusion. Figure 2.2.17 a and b show the floating ammeter and the preferred ground connection for marine system. The available grounding system includes insulated neutral, earthed Neutral and resistance earth Neutral System. The insulted neutral is favored for marine application because of:

1. This system is totally insulated from the ship’s hull
2. This system maintains continuity of power supply to the equipment even in the event of single phasing fault.
3. This ensure power supply to critical equipment
4. The power supply to the equipment can disrupt only if two single phase faults occur simultaneously in two lines which is then equivalent to short circuiting faults But such fault occur very rare

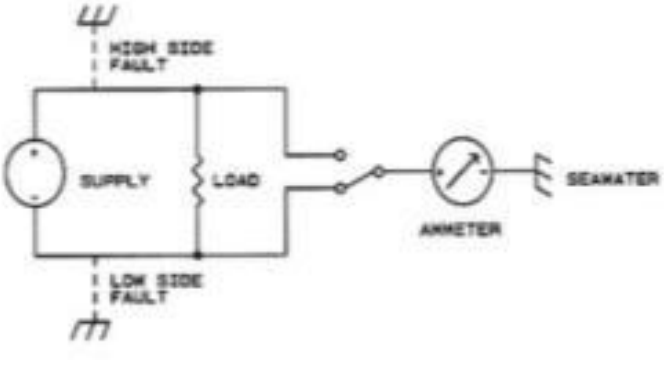


Figure 2.2. 14: Floating ammeter, Insulation earthling

Each side of each supply voltage is alternately connected to frame ground through a current limited ammeter. If a ground fault exists on the opposite supply rail, current will flow through the meter. This approach can be extended to monitor several supplies of differing voltages with a shared common rail, at the expense of a more complex troubleshooting flowchart. Action must be initiated to continue to remove, or reduce to a minimum, the causes of recurrent problem areas. Personnel are encouraged to become familiar with Article 250 of the National Electrical Code (NEC), which deals with grounding requirements and practices. Factors which influence the choice of selecting system ground:

i. voltage level of the power system
ii. transient over voltage possibilities
iii. types of equipment on the system
iv. cost of equipment
v. required continuity of service
vi. quality of system operating personnel and
vii. Safety consideration including fire hazards.

Distribution systems of ships are usually having their neutral points earthed to the ship's hull through a resistor. The resistor in neutral line limits earth faults currents and protects equipment

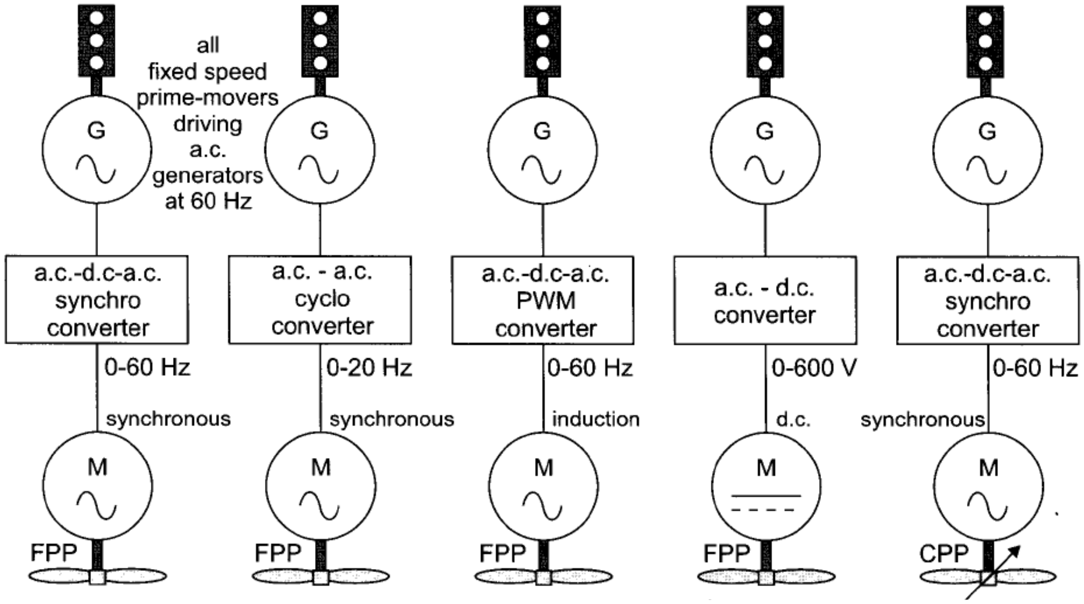
Power Switching, Telemetry and Control

Power switches were required for each load, or group of loads, on the vehicle for power tolerant. High power DC switching is more difficult, due to two practical issues. Mechanical switching elements require elaborate arc suppression measures (vacuum or arc blowout), since unlike AC current, DC has no naturally occurring zero crossings that allow the arc plasma to dissipate. Solid state switching elements inevitably have a few volts of "on" state voltage drop, and generate dozens of watts of waste heat. Both problems make compact packaging difficult [12], [13].

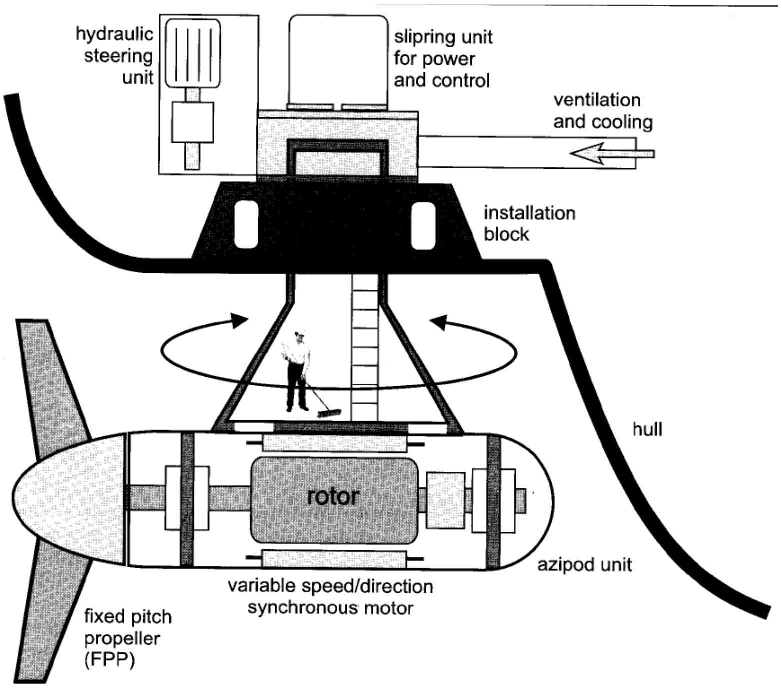
It is important for ground fault isolation of the load to have switch control and telemetry as part of the ROV distributed data system. Some could have Instrument Bus Computer (IBC) switches are rated in amapere and voltage, mostly power by MOSFETs, driven directly by photovoltaic optoisolators. Shunt resistors allow current to be sensed by an onboard A/D converter and reported over the backplane..Beside the switch other power interlock devices that can be employed for switch board system are circuit breaker. Circuit breaker comes in forrm of air circuit breaks, oil circuit breakers, air-ballast circuit breakers, gas (sf6- sulphur hexafluoride) circuit breakers and vacuum breaker.

Air circuit breaker are used for low voltage where arc chutes and arc contacts are incorporated. Air blast circuit breakers is a different type that are use for high voltage line , they can handle high pressure at about 30kg/cm^2 air blown during the operation of circuit breaker, thus the operation is too noisy. Oil circuit breaker normally use Napthenic base petroleum [$(CH_2)n$] which have been carefully refined to avoid sludge or corrosion. the are expected to excellent dielectric strength high thermal conductivity and prone fire prone to fire hazard, leakage/contamination.SF_6 circuit breaker is most accepted circuit breaker , it is made of chemically very stable, non flammable, non corrosive, non poisonous, colorless and odorless gas with Limits the sonic velocity (1/3 of air). It has Excellent dielectric strength, about twice of air. it can be used for high voltage and it has low GWP (global warming potential is high) and Lifetime 3200 years. Vacuum circuit breaker can also handle high voltage. The arc remains in the diffused column mode [11].

The control system controls the different functions of the ROV, this include the propulsion system , switching of the light(s), video camera(s), relay, digital fiber optics, digital, computer and subsystem control interface. The control system has to manage the input from the operator at the surface and convert it into actions subsea. The data required by the operator on the surface to accurately determine the position in the water is collected by sensors (sonar and acoustic positioning) and transmitted to the operator. Control systems are program to maintain required sequence and feedback operation. Today most control system utilizes PLC (Programmable Logic Computer). This is used in numerous manufacturing processes since it consists of easily assembled modular building blocks of switches, analog in/outputs, and digital in/outputs. Control stations vary from large containers, with their spacious enclosed working area for work class systems, to simple PC gaming joysticks [15], [16]. Figure 2.2.18 shows operation of semiconductor control.



a.



b.

Figure 2.2. 15: a) Motor frequency control, b) Azipod system

With the rise of robotics as a sub-discipline within electronics, further focus highlighted the need to control robotic systems based upon intuitive interaction through emulation of human sensory inputs. Digital control systems arose, more complex control matrices could be implemented much more easily through allowing the circuit to proportionally control a thruster based upon the simple position of a joystick control coupled with programmable logic circuits interface. The more sensors available to the 'human' that allow intuitive interaction with the 'robot', the easier it is for the operator to figuratively operate the vehicle from the vehicle's point of view.

Data Transmission and Protocol

Most ROV have spare twisted pair of conductors for hard-wire communication of sensors from the vehicle to the surface. This make sensor system to not need engineering support from the ROV manufacturer in order to design these sensor interfaces. The weakness is incompatibility of the transmission protocol to share the single data line, only one instrument may use the line at a time. Available industry standard protocols for transmissions is TCP/IP, RS-485, and RS-232, while useful and seemingly ubiquitous in the computer industry, is distance limited through conductors, thus causing transmission problems over longer lengths of tether. The move toward open source PC-based sensor data processing has led to the production of data protocol converters for use in ROV sensor interpretation. Most small ROV sensor manufacturers transmit data with the RS-485 protocol, requiring a converter at the surface to both isolate the signal and to convert it to USB (or RS-232) protocol for easy processing with a standard laptop computer. Standards for these protocol converters are slow in evolving (due to the size of the customer base).

Conclusion

The challenges of proactive culture towards accident occurrence near population and prevention of environmental consequence of accident evolved requirement for maritime activities to operate deep water. The importance of ROV in development of new technology to meet this challenges is highlighted, this include, data collection, installation and monitoring. Likewise, the need for more power is highlighted and system requirement to meet power requirement ROV for deep water Operation is discussed. ROV system integrator must become familiar with the wiring and pin arrangement for these converters that will be instrumental to HVDC to ROV system as well as to assure data transmission from the sensor, through the vehicle and tether to the software at the surface, is achieved. Power sensor and data throughput reliability promise greater the ability for deepwater to deliver to the operator the necessary job-specific data as well as sensory feedback needed to properly propel,. Maneuver and control ROV for deepwater operation.

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