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# Governing of DC Power in DC Micro Grid System with Renewable Energy Sources

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**ABSTRACT**
This paper with controlling of DC power in DC shipboard power. Shipboard power system experience disturbances due to variations in load. Whenever a fault occurs in load system power varies. In this paper the DC power system is controlled by automatically detecting disturbances. The proposed method includes self-governing fault detection and controlling of DC power. The shipboard power system consists of a challenge related to restoration. The reliability and flexibility of the system can be improved with effective integrated Energy Storage Devices (ESD). A DC bus distribution system developed. In this paper Furthermore, this shipboard management system may be implemented for Indian ship for optimal power management.

**Keywords:-** DC Power, DC Micro-grid, Matlab, Energy Storage Devices.

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**INRODUCTION**

The ships are used for both military and commercial purposes which works hinge on electricity are empowered by integrated power systems (IPS), are to meet increasing demand. In critical conditions i.e., when there is change in load or IPS component failure these then they provide real-time management for dynamic configuration to support system.
Recently, there is much advancement in controlling and managing DC micro grids. These advancements have been used in applications such as traction, smart buildings, shipboard power systems. There is extreme development in semiconductor devices and power electronic devices over last two decades. They made a way for advanced electrical networks which are useful in automotive, space, and marine applications. These systems deliver with high efficiency and reliability.

It is difficult to preeminent optimal performance without interruption with a dynamic load. The protection schemes can detect faults and isolate them but they do not consider the optimization constraints or balance the power and after fault isolation. To meet the increasing DC ship-board power demand all the electric ships are implementing the integrated power system. They have to manage the power for dynamic profile to support the system critical operations when there is change in dynamic load or IPS failure.
A new method is introduced which control and optimally reform a DC power system while automatically detecting system disturbances. A dynamic approach is proposed using time scale separation. The aim is to provide coordination between system protections to validate that the system will be steady at all stages of operation even when there is a disturbance. To implement and certify the approach, a DC-hinge ship board power system is employed. As the need for electrical power has been increasing there should an alternative solution to preeminent reliability. To preeminent reliability the restoration and recover after fault on system is needed. In

such cases the power system need storage devices to provide back-up power. In order to preeminent the reliability and pliable operations in shipboard power system, it is integrated with Energy Storage Devices for restoration.

## II DC.SHIPBOARD POWER SYSTEMS

The ships used for both military and commercial purposes which works hinge on electricity are empowered by integrated power systems (IPS), are to meet increasing demand. In critical conditions i.e., when there is change in load or IPS component failure these then they provide real-time management for dynamic configuration to support system. Recent advancements of naval ships engage an integrated power system. In IPS systems, power generation, power conversion and distribution networks are regale to loads by an integrated electric shipboard power system (SPS). By using IPS the pliable increases between propulsion and loads. In Integrated Power System architecture all the loads are regale by a common electrical power bus which enables handling of the loads and generation sources more optimally and efficiently, and is able to direct power to vital loads on demand. This system includes distributed generation, energy storage, system automation, network reconfiguration, dynamic power allocation, and condition-hinge preeminent. SPS have different types of load which have different characteristics. The efficiency and reliability of supply are reliant on SPS architecture. Therefore, awareness is paid to the shipboard power system architecture in terms of system control, protection, stability, reliability, efficiency. Moreover, sources, storage elements that are needed to increase the reliability, stability and security are scrutinized.

## III INTEGRATED POWER ARCHITECTURE (IPA)

The Integrated Power Architecture interprets 6 functional component and the power, control and statistics relationships between them. Every IPS module related to one of the IPA components. A power relationship is the transfer of electrical power between two functional components. A control connection mentions about transmit the commands from one functional element to another while anstatistics connection mentions that the transmission of data from one functional component to another. The six components are Power Generation, Power Distribution, Power Conversion, Power Load, Energy Storage and System Control. The IPS yield electric power to all loads, including propulsion, via a number of electric generators. This type of architecture is depicted in Figure 3.1. There are many advantages using IPS like mitigated number of prime movers, reduced shaft lines, pliable between propulsion and load, improved efficiency.

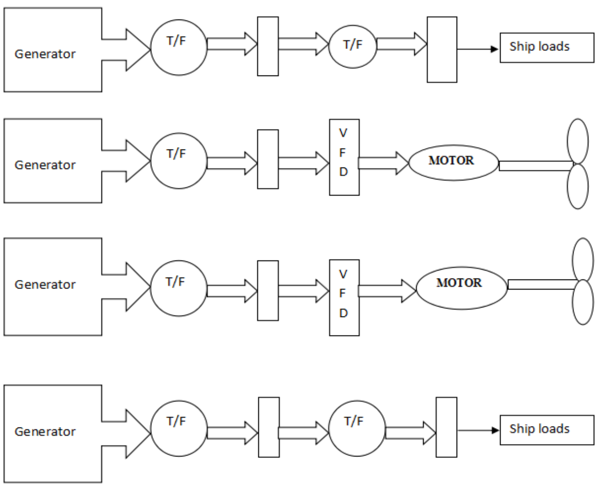


**Figure 3.1:** Integrated Power System architecture.

**3.1.1 Power Generation:**

A power generation is one IPS element which converts fuel into electrical power. The generated electrical power has to distribute power yields to supply to loads. A power generation function element exchanges control and statistics only with system control elements. The power generation on SPS might use gas turbine or diesel engine, a generator, a rectifier. As there are new advancements in renewable distributed resources which can be replaced in place of gas or diesel engines. Practically solar panels, fuel cells, wind turbine can be used.

**3.1.2Power Distribution:**

A power distribution functional component transfers electrical power from generator to load. Control and statistics signals can be transported only with system control component. Power distribution module embrace of bus duct, cables, switchgear and fault protection equipment.

**3.1.3 Power Conversion:**

To transform electrical power from one form of power to another power conversion components are used. Power may be transported only to and from power distribution element. Control and Statistics signals can be exchanged only with System Control Functional Components. Power conversion module generally embraces of a solid state power converter. Alternative possibility for power conversion module is a motor-generator set. The power conversion equipment accompanies with generator and motors are part of generation and load. But they doesn't include in power conversion functional element.

**3.1.4 Power Load:**

A Power Load Functional Element inherits electrical power from one or more Power Distribution Functional Components. Under transient cases the power load optimally delivers power to few power distributional components.

A Power Load may exchange control and statistics signals with System Control Functional Components and non-IPS systems i.e., external system. Associated Power Load segments incorporates Propulsion Motors and ship service loads.

**3.1.5 Energy Storage:**

Energy storage component stores energy. Power is transported to and from few power distribution elements via electrical power. Energy Storage Functional Element exchanges control and statistics signals with only System Control Functional Components.

An Energy Storage Device Subsystem is very necessary for shipboard power system along with terrestrial electrical systems. This element helps in storing large amount of energy which can be used as back-up. During any fault conditions electrical system can be fed by ESDs. Outage of electrical equipments and other parts or operational issue may occur if ESDs fail to provide energy during faults. In this project battery is worn as Energy Storage Device. ESS technologies are technologically feasible today few of them are Flywheels, the Superconducting Magnetic Energy Storage (SMES), Battery Energy Storage System (BESS), the Compressed Air Energy Storage (CAES), the Super Capacitors and Pumped Hydro Storage (PHS). Whatever the system may be either AC or DC, for charging and discharging purpose the ESS technology requires power converters. Mostly used ESS is Uninterruptible power supply (UPS), with batteries as backup power source.

**3.1.6 System Control:**

A System Control Functional Element embrace of the software which coordinates multiple other Functional Components. A System Control Functional Element receives statistics from functional components and external systems i.e., non-IPS.

### 3.2 Visualization for Shipboard Power System

Electricity on ship has to provide power generation and distribution, control and few basic power electronics operations. The space and weight parameters limit the amount of discharge in system for restoration purposes. The resistive losses in SPS are nearly negligible because of tightly coupled distribution network. A SPS generally made up of sundry integrant such as generators, cable, switchboards, load centers, circuit breakers, bus transfer switches and loads. A SPS composed of 3 phase generators which is in the form of ring configuration and concatenated as delta using generator switchboards. Circuit breakers are inter concatenated with the generators which permit the power conducts from one switchboard to another.

Load midpoint and loads receive supply from switchboards. Some loads get supply directly from load midpoints. Some loads are concatenated to power panel. Load midpoints also supply power to power panels to some loads which are concatenated. The power to load centers, power panels and loads are regale through branch. These feeders are generally radial in nature. In radial connection each load gets supply from only a single source at a given time. The radial type systems have merits like adroitness of fault location and isolation, and protective devices cooperation. Generally loads are categorized into 2 forms that is either vital loads or non-vital load which can be either three phases or single phase. For vital type of loads, the power transfer is through two different paths that is normal path and alternative path. The power transfer for requisite loads is via Automatic Bus Transfers (ABTs) or manual bus transfers (MBTs). Practically normal path is choosed path. Generally Automatic Bus Transfer (ABTs) is prefers normal path but when the normal path is not available then it goes for alternative path.

Circuit breakers and fuses are provided for protection at different locations of the system. These protection devices isolate the faulted loads generators or any distribution system from un faulted part of system. These faults can be due to any fault in cables or generator fault or any load faults. If there any fault in generation and protection devices isolates that part then the re preeminent part will be left without supply. This may result in system shutoff. There should be swift rehabilitation of supply to these un faulted section is required in order for system survivability. During the refurbishment process the generator and cable capacity should not be disobeyed and at each node the magnitude of voltage has to be within tolerable limits.

Shipboard power system has resemblance with isolated demarcated utility systems where generators are the only radix of the supply for loads on system. Nonetheless, there are several imbalances between utility and SPS, such as ships which have huge dynamic loads correlative to generator size and large hunk of nonlinear loads relative to power generation capacity, and transported lines which are not approaching as crucial as for utilities because of their miniscule lengths.

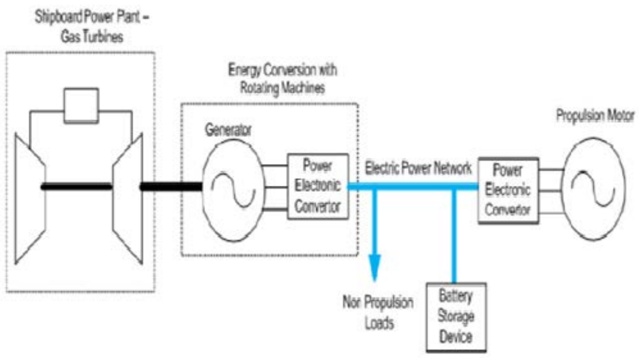


**Fig 3.2:** Shipboard Integrated Power System.

The system characteristic of electrically integrated SPS is very akin to islanded micro grid except that is not roboted and will have proportionately debilitated power steadiness since the generator capacity is slam sized to the load demand. In order to preeminent shipboard power system accuracy it has to be robotic. It is also proved that automation gives best results than manual control. In this process, multiple power generation capabilities are placed throughout the ship. The efficiency of shipboard can be improved by automating the system. Self-operating methods for shipboard power systems, akin as failure assessment, refurbishment and reconfiguration, need good feature and statistics retrieval tools to gauge the effect of battle havoc on the electrical systems.

## IV SIMULATION MODEL AND RESULTS

The proposed method is implemented and modeled in MATLAB version 2016a with Intel quad core 7$^{th}$ generation.

### 4.1 DC Power System without ESS Device

The simulation of dc shipboard power system without ESS device is shown in figure 4.1.

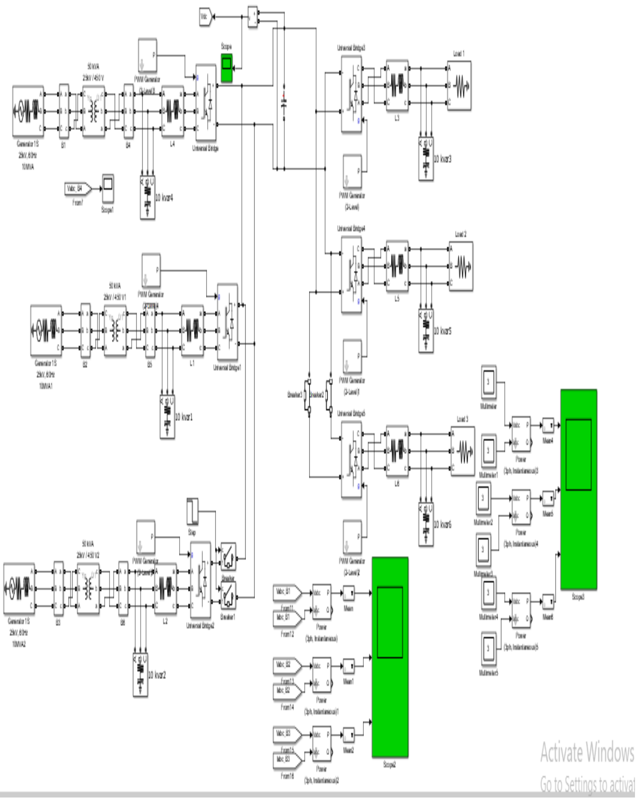

**Fig 4.1:** Simulation of DC Power System without ESS.

In place of diesel generator to make circuit simple direct three phase source is used which produce rated voltage of 25kv 10MVA power with 50 Hz frequency. To reduce voltage to rated three phase voltage i.e., 415 a step-down transformer is used to decrease voltage. Three phase measurement device is used to gauge the voltage and current of generator and transformer. To avoid any harmonics or ripples present in voltage and current filters are used. Two filters are used in the circuit i.e., RL and RC filters are used to remove harmonics and RC is used to support voltage. The RL filter embrace of series concatenated resistance and inductance. The RC filter embrace of series concatenated resistance and capacitor. The ripple and harmonic free voltage and current are provided to converter.

At source side converter acts as rectifier. This rectifier converts the AC into DC. In matlab simulink for converter universal bridge is used. This universal bridge is transforms AC into DC. To on the universal bridge gate triggering has to be regale. In order to provide gate triggering pulse, pulse width modulation module is used. In matlab two level pulse width modulations is used.

This DC power is given to bus bar i.e., DC bus bar. The bus bar transfer DC power. There are three generators which produce AC and three converters which transform AC to DC. All the converted DC power which is given to the bus bar is tied. That is all bus bars transferring DC power are tied together. The capacitor is concatenated with reference voltage as 750v. This capacitor voltage is termed as DC bus reference voltage. To measure the voltage of DC bus bar voltage measurement device is used and to observe the voltage waveform scope is used. From the DC bus bar the power is transported to the converter act as inverter which converts DC into AC. And again filters are used then regale to the load.

A protective device that is circuit breaker is used. DC circuit breaker is used after rectifier and before inverter. DC circuit breaker is used as protecting device. To measure the output power three phase active and reactive power measuring module is used which takes input as voltage and current and calculates the active and reactive power internally. Scope is used to observe the waveforms.

The circuit is without energy storage system so if there is any fault and system is isolated then the load doesn't get regale with power which causes reliability problem.

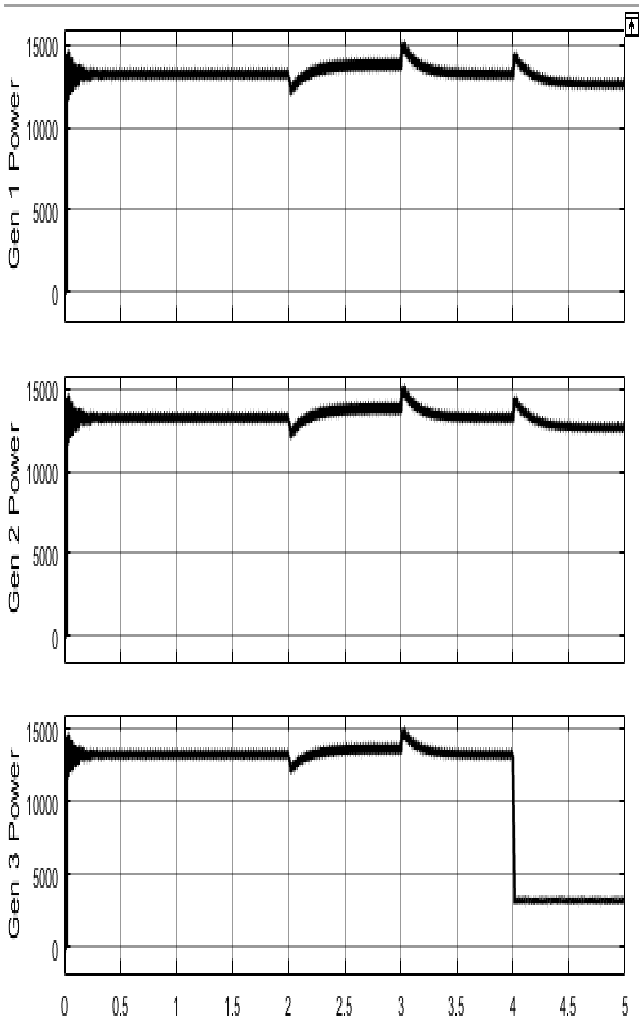


**Fig 4.2:** Waveform of Generation Power.

Two disturbances are created which occur commonly in system to validate the feasibility of the proposed approach. Two disturbances are generator loss, load start. The three generators output power waveforms are shown in figure 4.2.

Whenever there fault in generation the protecting device that is circuit breaker isolates the faulted part with non faulted path. At generator 3 the there is fault at generation at 4sec it becomes isolated and doesn't generate power. In matlabsimulink to produce fault the circuit breaker is set to trip at four seconds.

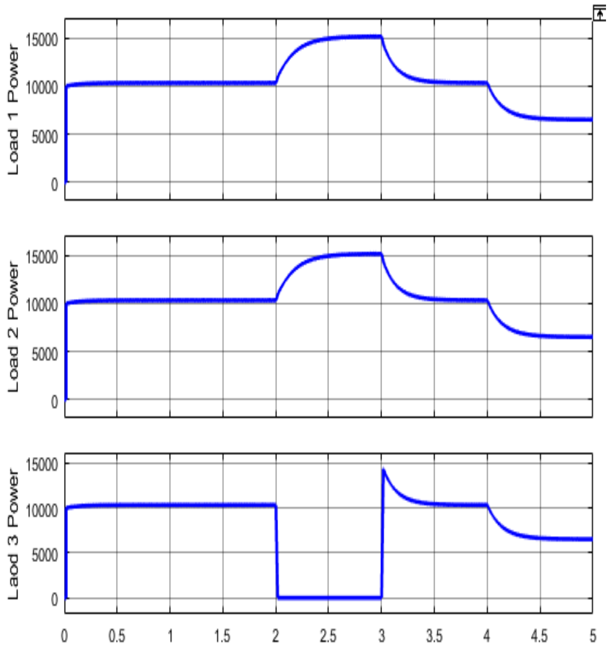


**Fig 4.3:** Waveform of Output Load Power.

The load power waveform is shown in figure 4.3. At four seconds the power is not generated due to generation fault i.e., power doesn't gets regale to the load. But in this concept all the bus bars are tied to together and a reference value is set at 750v. So whenever there is any fault occurred in generation the loads get partially regale. Because of the tied bus bar the power is distributed equally. In figure 7.3 it can be seen that the load is disconcatenated at 2-3 seconds so during that period the excess generated power is wasted. And because of the loss of one generated and distribution of power equally the loads may experience some large ripples and partially power is received by load that is load is not fully regale. Because the load needs 10kw of power but it regale with less than 10kw after fault occurrence. So in order to make power ripple free and to utilize the extra generated power and to supply the load with full supply even when fault has occurred Energy Storage System (ESS) is used.

**4.2 DC Shipboard Power System with ESS Device**

The proposed method is implemented and modeled in MATLAB version 2016a with Intel quad core 7$^{th}$ generation as shown in Figure 4.4. Two-level pulse width-modulated (PWM), voltage source converters (VSCs) are used to convert the AC (3-φ 440 VAC 60Hz) power produced by the three-phase generators which is again stepped down using transformers. The DC bus reference voltage is set to 750 V.

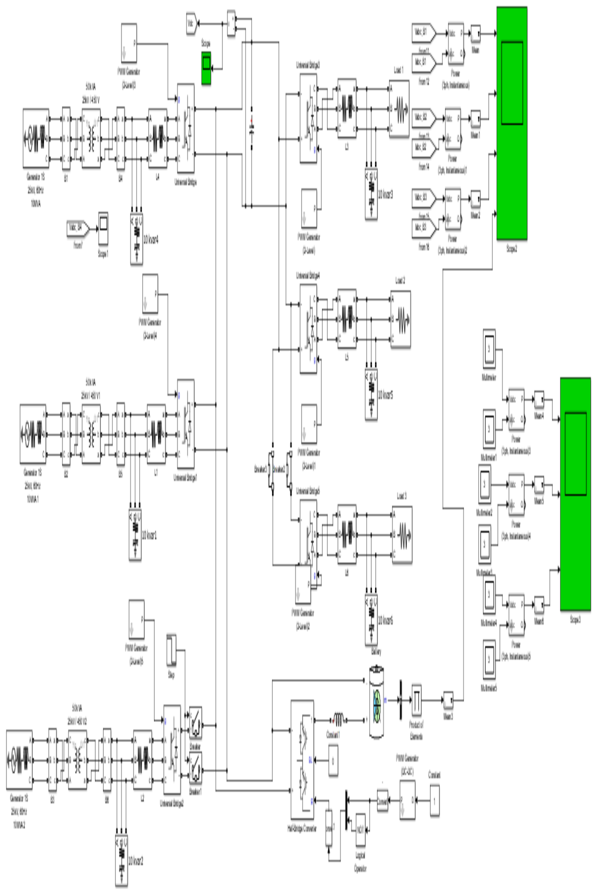

**Fig 4.4:** Simulation of DC Power System with ESS.

As the feedback path Energy Storage System is used. A battery of 650V 400Ah is used in ESS and concatenated to the DC bus through a bi-directional DC/DC converter. In matlab for DC/DC converter half bridge converter is used. Pulse width modulation has been regale to it.

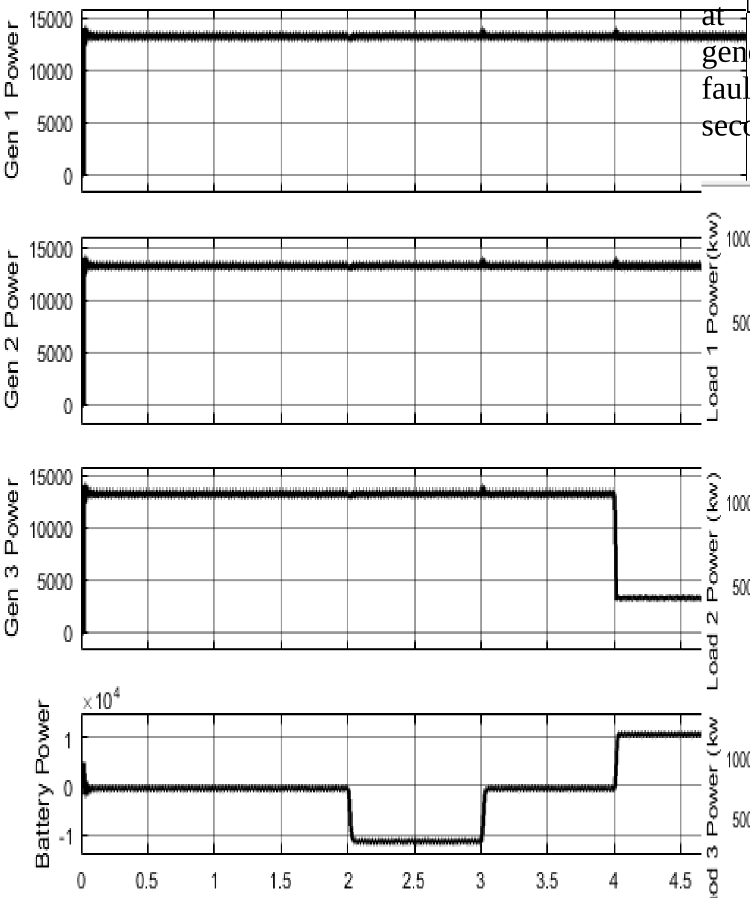


**Fig 4.5:** Waveform of Generation Power.

Two disturbances are created which occur commonly in system to validate the feasibility of the proposed approach. Two disturbances are generator loss, load start. The three generators output power and battery power waveforms are shown in figure 4.5. And battery power is also shown in the waveform. If the battery power in waveform is at zero w then the battery is neither charging nor discharging. Whenever it is at +1 or greater then it charging and if it is on -1 or lesser then it is discharging.

Whenever there fault in generation the protecting device that is circuit breaker isolates the faulted part with non faulted path. At generator 3 the there is fault at generation at 4sec it becomes isolated and doesn’t generate power. In matlabsimulink to produce fault the circuit breaker is set to trip at four seconds.

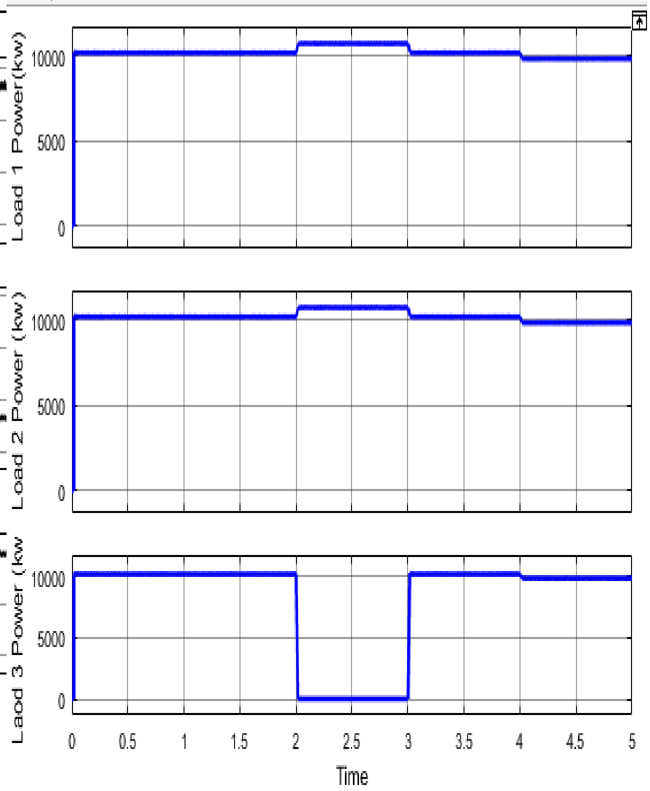


**Fig 4.6:** Waveform of Load Output Power.

The load power waveform is shown in figure 4.6. At four seconds the power is not generated due to generation fault i.e., power doesn’t gets regale to the load. But in this concept all the bus bars are tied to together and a reference value is set at 750v and ESS is used as feedback. So whenever there is any fault occurred in generation the loads get regale through the feedback path. That is whenever there is need for power then batter in the ESS injects the voltage into system through a converter. Whenever the battery is injecting the power into the system then converter acts as boost converter. In the figure 4.5 it can be observed that while injecting the power the batter power is at +10kw. The load power of load 3 can be observed in figure 4.6 that at four seconds there is fault in generation and the power is not generated form generator 3 but the load get regale with power of 10kw i.e., required power through ESS.

In fig.4.6 it can be seen that the load is dis-concatenated at 2-3 seconds so during that period the excess generated power is wasted. Without ESS this power gets wasted. That is whenever there are disturbances at load then the circuit breaker isolates the faulted path with non-faulted path. So the power generated is not regale to load. In order not to waste the excess power the feedback path absorbs the excess power. That it when there is extra power generated then the ESS devices battery absorbs it through DC/DC converter which acts as buck converter and absorbs the power. The battery waveform can be observed from figure 4.5 that whenever it is observing the excess power generated the battery power is -10kw i.e., it is charging. The battery uses extra power to charge itself. The battery is charging itself whenever there is excess power and it is discharging when it is injecting power.

**4.3 DC Shipboard Power System Using Solar Power System**

The proposed method is implemented and modeled in MATLAB version 2016a with Intel quad core 7th generation as shown in Figure 4.7. Two-level pulse width-modulated (PWM), voltage source converters (VSCs) are used to convert the AC (3-φ 440 VAC 50Hz) power produced by the three-phase generators which is again stepped down using transformers. The DC bus reference voltage is set to 750 V. solar panels are used for power generation.

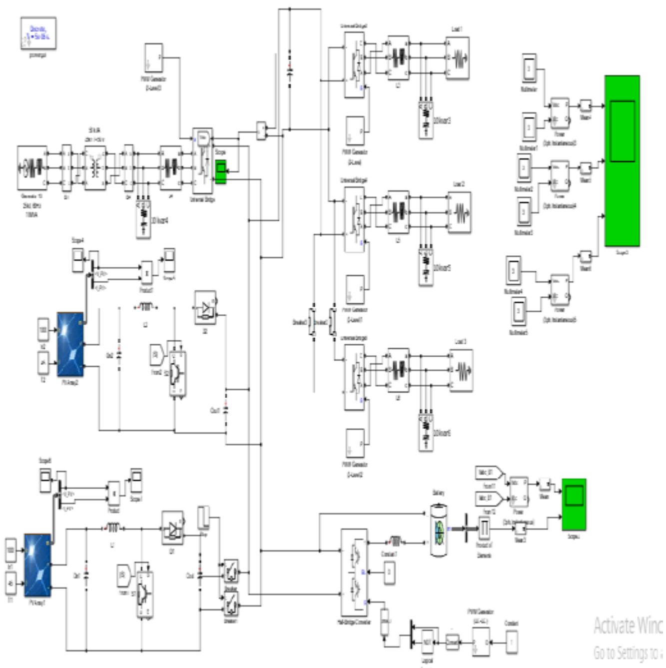

**Fig 4.7:** Simulation of DC Power System using solar power system.

Whenever there fault in generation the protecting device that is circuit breaker isolates the faulted part with non faulted path. At generator 3 the there is fault at generation at 4sec it becomes isolated and doesn't generate power. In matlab simulink to produce fault the circuit breaker is set to trip at four seconds.

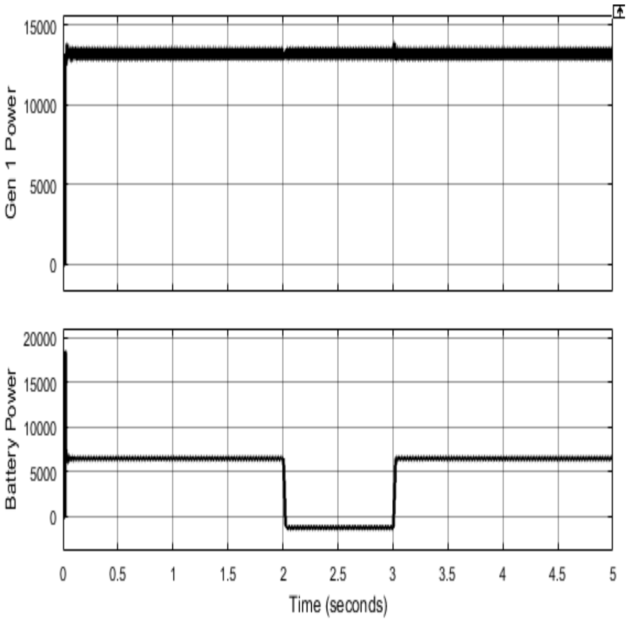


**Fig 4.8:** waveform of generator 1 and battery power.

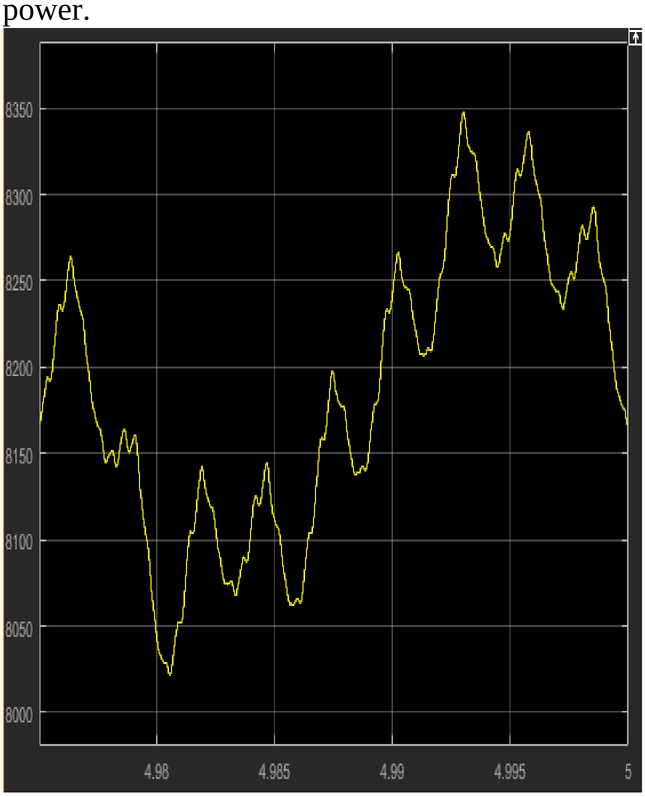


**Fig 4.9:** Waveform of solar output power.

In place of 3 generators only one three phase generator is used for another 2 solar power plant is used and the solar output power waveform is shown in figure 4.9.

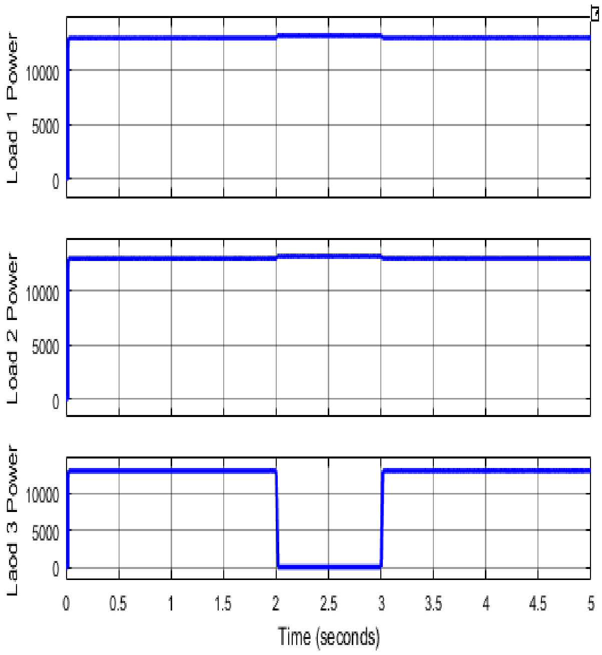


**Fig 4.10:** waveform of load output power.

The load power waveform is shown in figure 4.10. At four seconds the power is not generated due to generation fault i.e., power doesn't gets regale to the load. But in this concept all the bus bars are tied to together and a reference value is set at 750v and ESS is used as feedback. So whenever there is any fault occurred in generation the loads get regale through the feedback path. That is whenever there is need for power then batter in the ESS injects the voltage into system through a converter. Whenever the battery is injecting the power into the system then converter acts as boost converter. In the figure 4.8 it can be observed that while injecting the power the batter power is at +10kw. The load power of load 3 can be observed in figure 4.10 that at four seconds there is fault in generation and the power is not generated form generator 3 but the load get regale with power of 10kw i.e., required power through ESS.

In fig.4.10 it can be seen that the load is dis-concatenated at 2-3 seconds so during that period the excess generated power is wasted. Without ESS this power gets wasted. That is whenever there are disturbances at load then the circuit breaker isolates the faulted path with non faulted path. So the power generated is not regale to load. In order not to waste the excess power the feedback path absorbs the excess power. That it when there is extra power generated then the ESS devices battery absorbs it through DC/DC converter which acts as buck converter and absorbs the power. The battery waveform can be observed from figure 4.8 that whenever it is observing the excess power generated the battery power is -10kw i.e., it is charging. The battery uses extra power to charge itself. The battery is charging itself whenever there is excess power and it is discharging when it is injecting power.

### 4.4 DC Shipboard Power System Using multiple renewable energy soruces

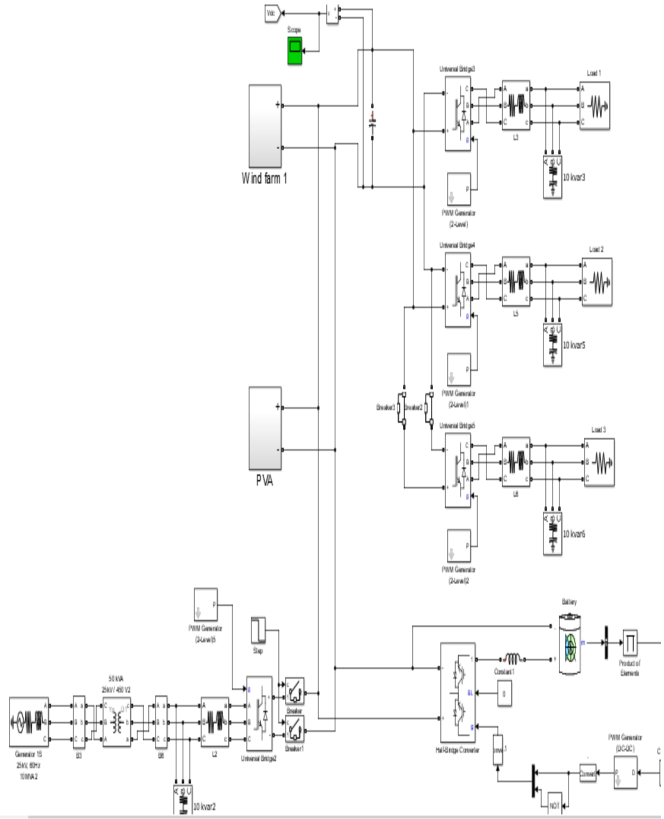


**Fig 4.11:** DC micro grid system with multiple renewable sources.

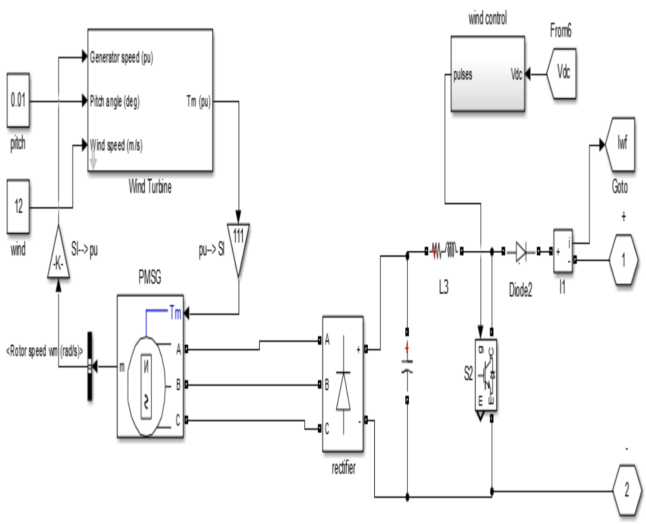


**Fig 4.12:** Wind farm modeling.

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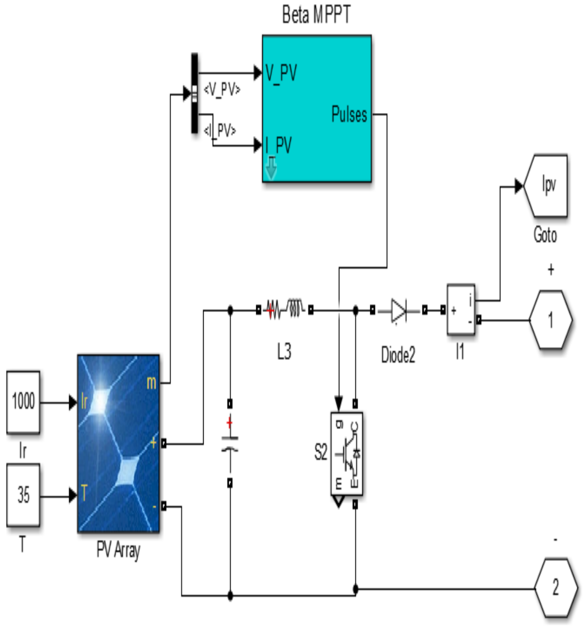


**Fig 4.13:** PVA modeling.

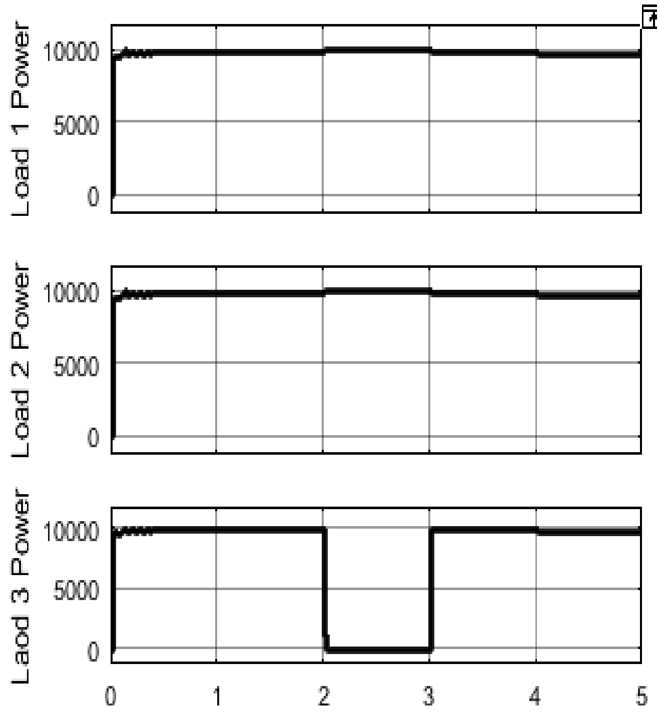


**Fig 4.15:** Load power consumption changed at 2sec and 3sec.

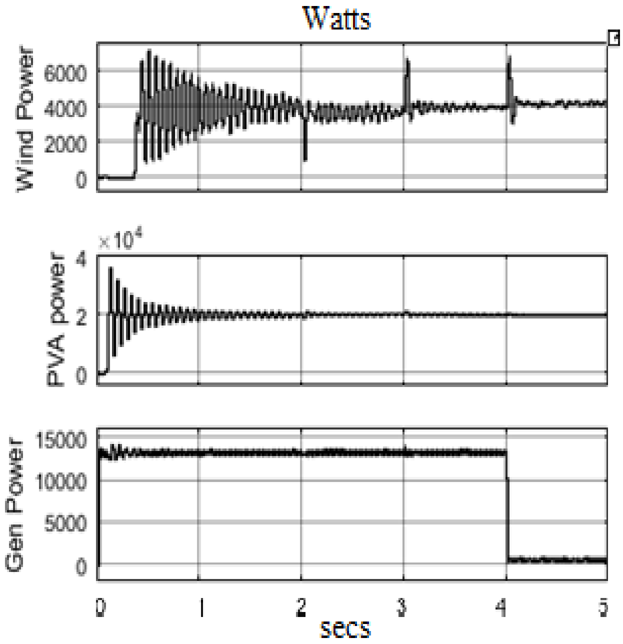


**Fig 4.14:** Power injected from sources connected to grid.

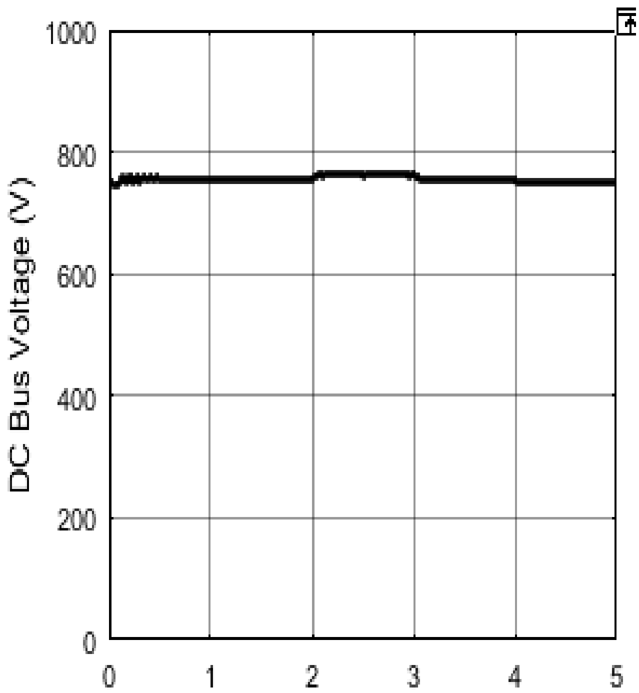


**Fig 4.16:** DC bus voltage at DC link.

**V CONCLUSION**

As the results indicate, the system re pre-eminent substantial at all points of the disturbances introduced at specific intervals of time and is optimized during the overall operation. The control system shows a faster recovery and robust performance regardless of the transient sources and more importantly it coordinates with optimization system to efficiently manage the output power from each generator to pre-eminent the overall efficiency. The communication interface between control system and the optimizer exchanges the statistics is fast, which a great advantage is considering the time-scale difference between the control system and the optimizer. This project proposes the controlling technique for DC power in shipboard power system. The proposed method is applied on DC shipboard and outcomes are presented. The results indicate that the system re pre-eminent substantial at every instance of time of disturbances which are introduced at specific intervals of time. The reliability of proposed method is high. The proposed Energy storage system is capable of producing quality results in terms of controlling of DC power in shipboard**.** As future work, sundry disturbances and faults at generators will be further investigated, as well as incorporation of intelligent systems and decision making techniques to achieve more robust and efficient operation.

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