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Simulation and Analysis of Dynamic UPS with Flywheel and Battery Back Up

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Abstract – In the current historiography the picture of consistent is that the uninterrupted as well as quality power supply. Flywheel energy storage and the battery storage have become one of the attractions in the field of uninterruptable power supplies. Nowadays static UPS systems are preferred for low-power applications, although rotary UPS systems offer some interesting advantages. A rotary UPS uses the inertia of a high-mass spinning flywheel (flywheel energy storage) to provide short-term ride-through the time of power loss. The flywheel also act as a buffer against power spikes and sags, since such short-term power events are not able to appreciably affect the rotational speed of the high-mass flywheel.UPS batteries are sized to provide backup power for periods measured in minutes. The period ranges from about 5 minutes up to around 1 hour, but is commonly about 15 minutes. A period of 15 minutes, more or less, is generally presumed adequate to allow an orderly shutdown of equipment. Flywheels, on the other hand, provide backup power for periods measured in seconds. The backup period for flywheels is commonly about 15 seconds. However, a flywheel alone will not provide backup power for a period long enough to allow an orderly process shutdown in most cases. In such critical conditions use of generator comes into context where a D.G set can entirely provide and can run orderly process plant for at least 12 hours of operation and after some breathing time it can be operated again, time which is sufficient for SEB power to restore.

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I. INTRODUCTION

Efficient regenerative energy storage is one of the great technical challenges of our time. Energy can be stored in the form of chemical, thermal, electromagnetic and mechanical form. Applications of mechanical energy storage devices include compressed gas facilities, pumped hydroelectric storage and flywheels. A flywheel stores energy in the form of kinetic (rotational) energy. Whereas each energy storage system has its inherent advantages and disadvantages compared to the others, it is the overall system performance and simplicity of flywheels that make them especially attractive for a variety of applications. With the introduction of frictionless magnetic bearings, the efficiency of flywheels for energy storage could be increased to an economically useful level. The main drawback of active magnetic bearings is the elaborate control system which is required to keep them operational. Increasing the reliability and reducing the complexity and cost of the system are still points of major concern in the field. For applications which are exceptionally critical concerning friction, such as flywheel systems for because it contributes to intrinsic bearing drag.

Layout Diagram and Analysis of Dynamic Ups with Diesel Engine & Flywheel

A flywheel is a simple speed drive increases system efficiency form of mechanical (kinetic) energy and allows the use of a smaller motor. storage. Energy is stored by causing a disk or rotor to spin on its axis.Energy is proportional to the flywheel's mass (more accurately, its mass moment of inertia) and the square of its rotational speed. In order to develop loss less magnetic bearing for long time and high speed application, new magnetic bearing is proposed which uses Lorentz force for bearing force. Stator-coil is constructed by four air core coil segments and the stator holder, while flywheel-rotor is constructed by two outer permanent magnets, two inner permanent magnets, back yoke and housing. Stator-coils are sandwiched between permanent magnets without contact and fixed to the base flame. Flywheel-rotor is attached to the shaft. A set of cylindrical permanent magnet generates closed loop flux path. Lorentz forces acts on coils. However, coils are fixed to base as a stator. Thus the reaction force acts on shaft . However, coils are fixed to base as a stator. Thus the reaction force is act on shaft .Bearing control uses this reaction force. The kinetic energy stored in a flywheel is proportional to the mass and to the square of its rotational speed according to

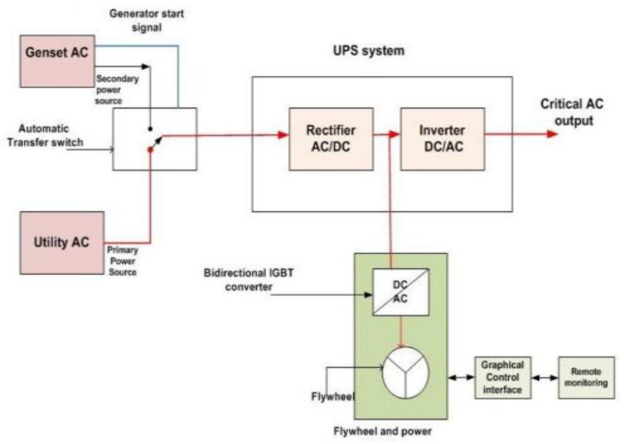


Fig.1 Layout of flywheel system

II. INTRODUCTION TO POWER QUALITY AND UPS UTILITY

The subject of power quality is very broad by nature. It covers all aspects of power system engineering, from transmission and distribution level analyses to end-user problems. Therefore, electric power quality has become the concern of utilities, end users, architects, and civil engineers as well as manufacturers. These professionals must work together in developing solutions to power quality problems:

- Electric utility managers and designers must build and operate systems that take into account the interaction between customer facilities and power system. Electric utilities must understand the sensitivity of the end-use equipment to the quality of voltage.
- Customers must learn to respect the rights of their neighbors and control the quality of their nonlinear loads. Studies show that the best and the most efficient solution to power quality problems is to control them at their source.
- Architects and civil engineers must design buildings to minimize the susceptibility and vulnerability of electrical components to power quality problems.
- Manufacturers and equipment engineers must design devices that are compatible with the power system. This might mean a lower level of harmonic generation or less sensitivity to voltage distortions.

Definition of Power Quality

Electric power quality has become an important part of power systems and electric machines. The subject has attracted the attention of many universities and industries, and a number of books have been published in this exciting and relatively new field.

Despite important papers, articles, and books published in the area of electric power quality, its definition has not been universally agreed upon. However, nearly everybody accepts that it is a very important aspect of power systems and electric machinery with direct impacts on efficiency, security, and reliability. Various sources use the term "power quality" with different meaning. It is used synonymously with "supply reliability" "service quality" "voltage quality" "current quality" "quality of supply" and "quality of consumption". Judging by the different definitions, power quality is generally meant to express the quality of voltage and/or the quality of current and can be defined as: the measure, analysis, and improvement of the bus voltage to maintain a sinusoidal waveform at rated voltage and frequency. This definition includes all momentary and steady-state phenomena.

Causes of Disturbances in Power Systems

Although a significant literature on power quality is now available, most engineers, facility managers, and consumers remain unclear as to what constitutes a power quality problem. Furthermore, due to the power system impedance, any current (or voltage) harmonic will result in the generation and propagation of voltage (or current) harmonics and affects the entire power system. The impact of current harmonics is generated by a nonlinear load on a typical power system with linear loads. What are the origins of the power quality problem?

Flywheel Dynamic UPS System

The consideration flywheel Dynamic UPS System is illustrated in fig. 3.23Schematically, it consists of:

- An isolating choke (of high inductance value) between the supply side and the load side.
- A synchronous machine connected on the load side of the above choke through a MV/LV transformer, depending on the system, a small coupling inductance may also be connected in series on the feeder between the connections point of the synchronous machine and the load side.

- A kinetic energy storage system, this may be a flywheel, or a special a synchronous machine with a very heavy rotor or whatever type of system able to store kinetic energy and to restitute whenever needed.

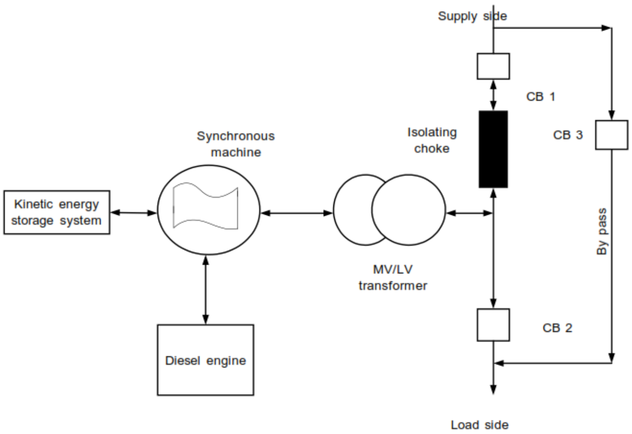


Fig. 2 Flywheel Dynamic UPS System

Finally a diesel engine that provides the required mechanical power in the case of long duration power cut or any detecting fault condition, power is provided to the load.

In fig.2 normal operating condition, circuit breaker CB1 and CB2 are closed and CB3 is open. The power supply is provided by the HV network through the HV/LV substation and the isolating chock. In case of disturbance on the supply side (limited voltage dips or very short power cuts), the voltage and frequency on a HQ feeder are regulated by the dynamic flywheel UPS system. When severe voltage dips or power cut occur on the supply side, CV1 opens. The UPS system is disconnected from the main network and operates in islanded condition on its HQ feeder. For the first few second, the mechanical power is supplied to the UPS synchronous machine by the kinetic energy storage system. Depending upon the configuration chosen by the manufacturer, the diesel engines are then started and progressively pick up the load. A part of produced power is used to reconstitute the kinetic energy reserve. After the disturbance has disappeared, the UPS system synchronizes itself with the supply side and then reconnects to the main network (CB1 closes).

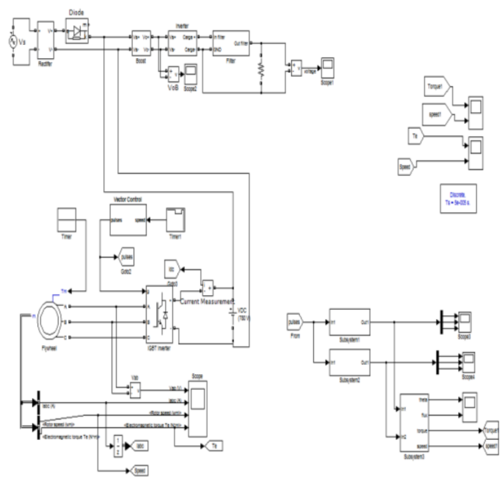
Uninterruptible Power Supply (UPS)

Systems provide uninterrupted, reliable, and high-quality power for vital loads. They, in fact, protect sensitive loads against power outages as well as overvoltage and under voltage conditions. UPS systems also suppress line transients and harmonic disturbances. Applications of UPS systems include medical facilities, life support systems, data storage and computer systems, emergency equipment, telecommunications, industrial processing, and on-line management systems. Generally, an ideal UPS should be able to deliver uninterrupted power while simultaneously providing the necessary power conditioning for the particular power application. Therefore, an ideal UPS should have the following features.

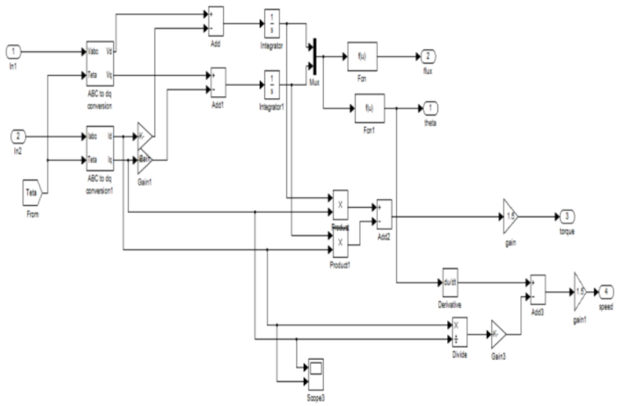
- Regulated sinusoidal output voltage with low total harmonic distortion.
- (THD) independent of the changes in the input voltage or in the load, linear or nonlinear, balanced or unbalanced.
- On-line operation, which means zero switching time from normal to backup mode and vice versa.
- Low THD sinusoidal input current and unity power factor.
- High reliability.
- Bypass as a redundant source of power in the case of internal failure.
- High efficiency.
- Low electromagnetic interference (EMI) and acoustic noise.
- Electric isolation of the battery, output, and input.
- Low maintenance.
- Low cost, weight, and size.

The advances in power electronics during the past three decades have resulted in a great variety of new topologies and control strategies for UPS systems.

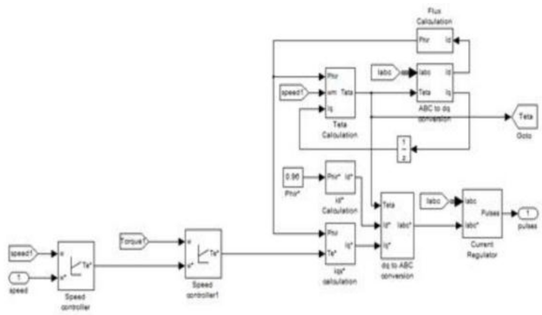
III. SIMULATION AND ANALYSIS FLYWHEEL MODEL



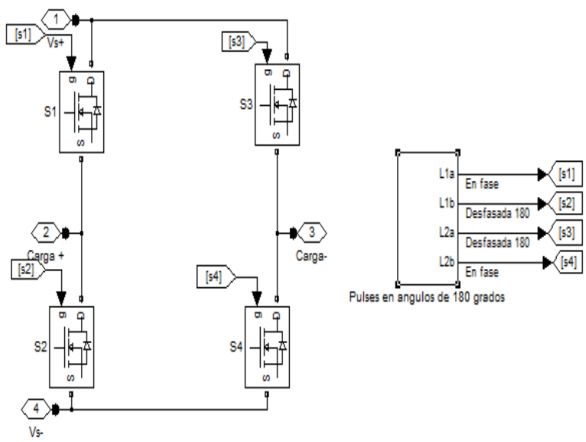
UPS Control System



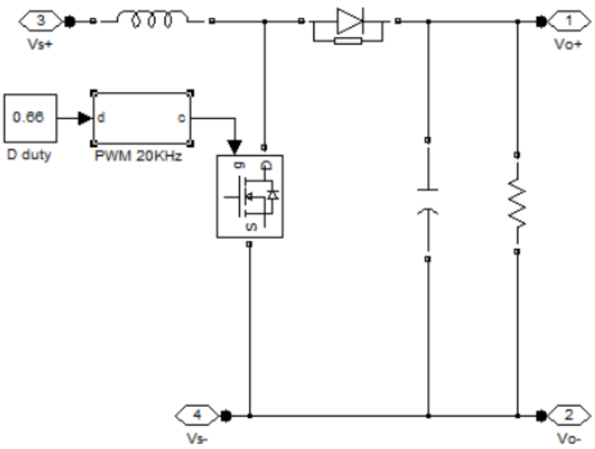
Vector Control



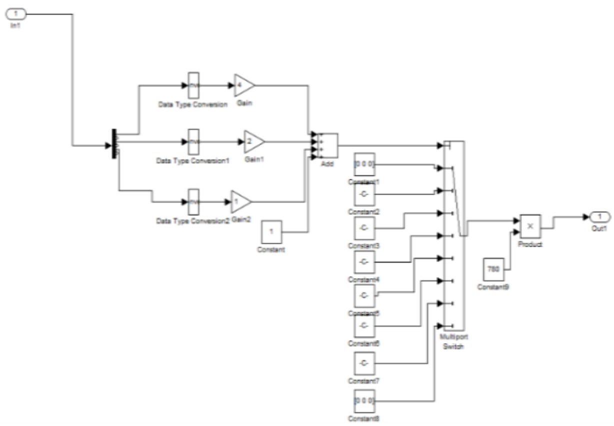
Inverter



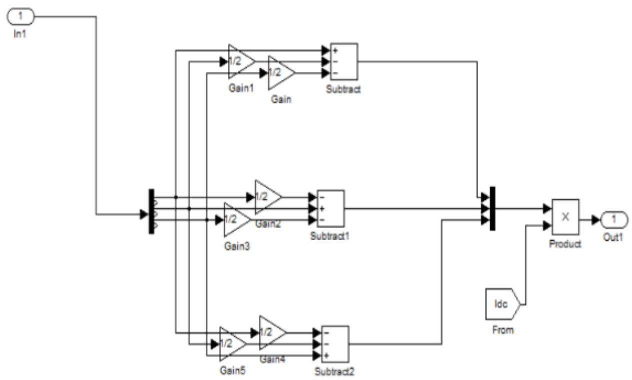
Boost Converter



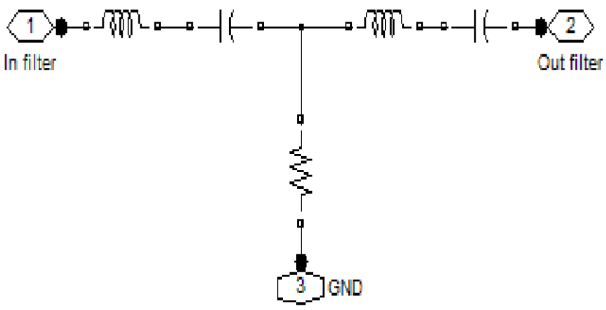
Gate Control Pulses-1



Gate Control Pulses-2



Filter



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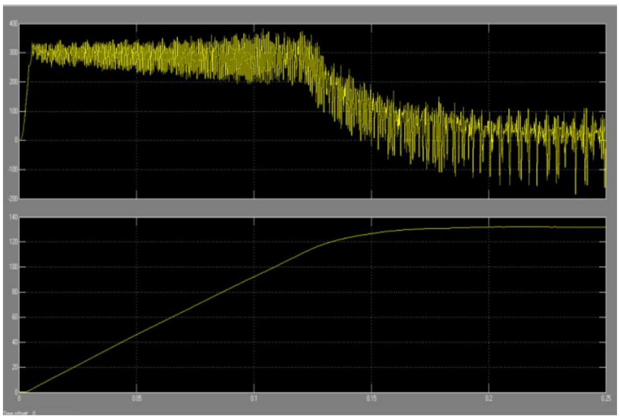
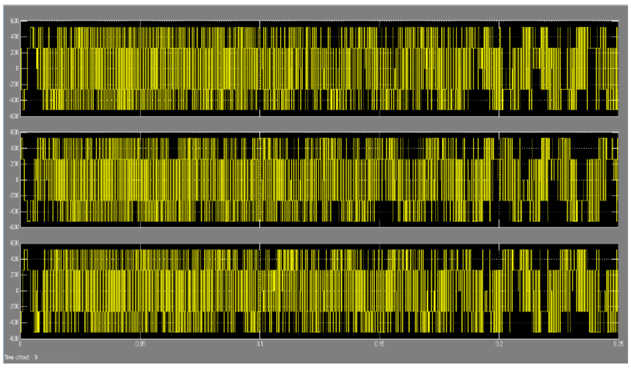
Simulation inputs

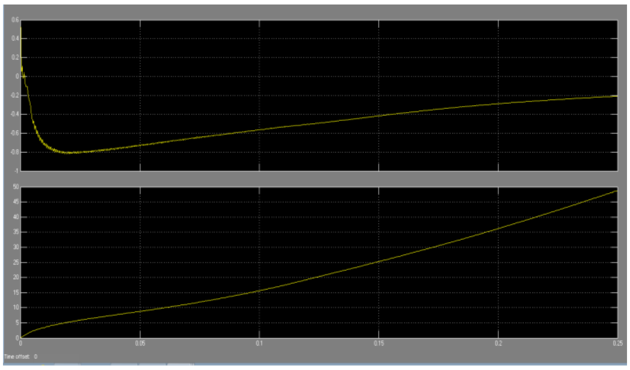
Torque and speed of FLWHEEL



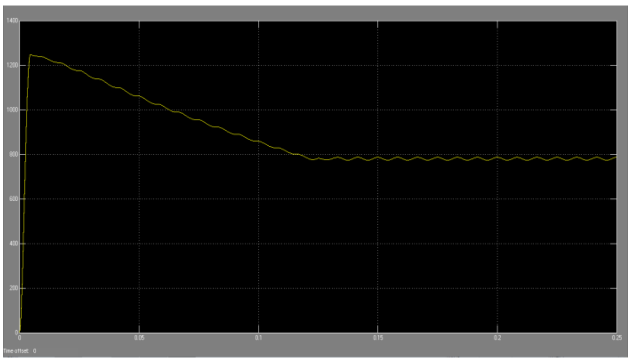
Gate Pulses



Flux angle and Variation

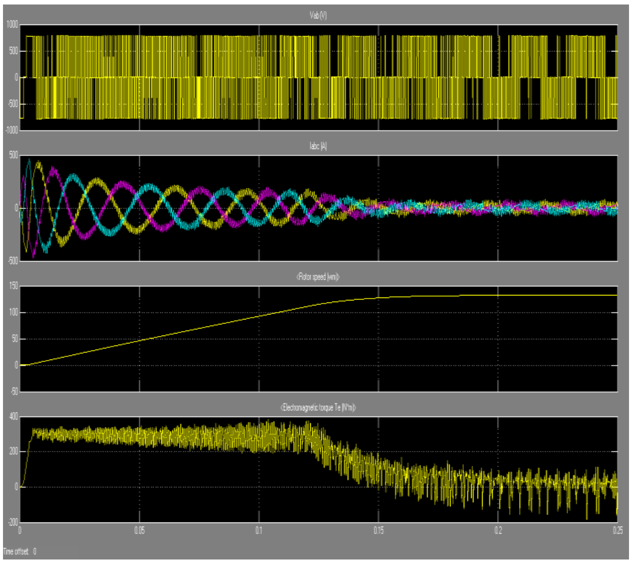


Boost Voltage

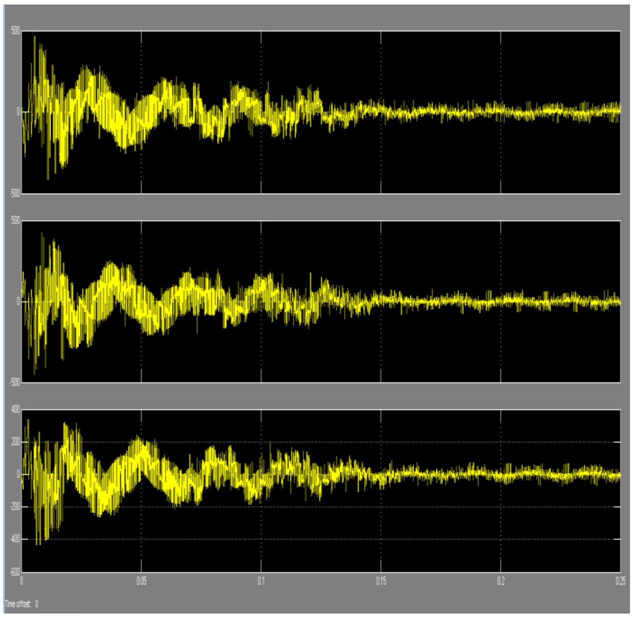


Output Parameters

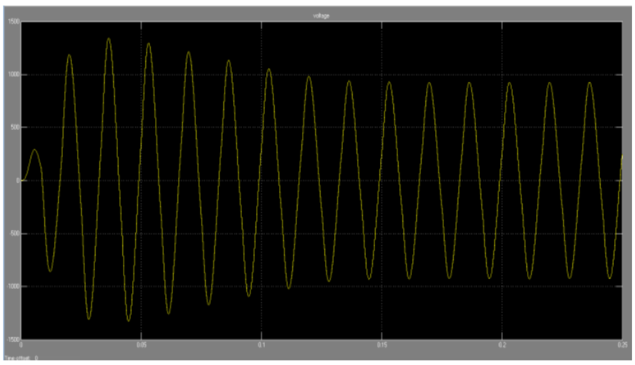
Flywheel Output Parameters



Output control Pulses



Stable Output Voltages



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Design Simulation and Analysis of Dynamic Ups with Diesel Engine & Flywheel:-

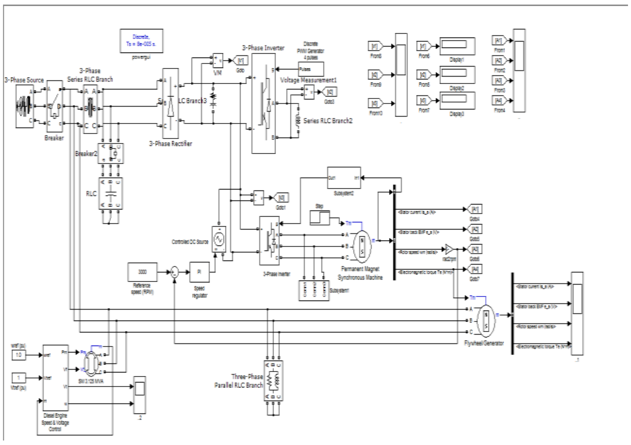

Fig-3 simulation diagram

When the Power Supply is Continue:

As in case of normal condition stator current in steady state is after 0.3S and in abnormal condition it is after 0.4S. if we do FFT analysis of stator current then in normal condition the fundamental is about 19.90% and in abnormal condition it is 33%.Fig. shows the topology of main power circuit of energy converter. From this topology, three converters are used in this system. When power is on, AC/DC rectifier will work. Then the control supply can work firstly. Thus the control system can be operated. The system can maintain for some time, because of using the flywheel energy storage unit. Motor converter can drive the three- phase permanent magnet brushless DC motor. The energy is stored in the flywheel as mechanical energy, when the flywheel is running at the high speed. Motor converter can also work as a rectifier, when needed, and convert mechanical energy hack to electrical energy. DC/AC inverter is aimed to supply constant voltage and constant frequency to the load in the charging mode or the discharging mode. Different types of electric machines can be used in an FES. The most common types are induction machines, and permanent magnet synchronous machines (PMSM). In this PMSM is used for the FES model. To model the motor- generator subsystem of the FES in MATLAB, the synchronous machine (SM) excitation system is performed by the standard excitation block provided in the MATLAB library. The model of diesel engine is presented in Fig. 5.5.1

The Output of the PMSM and Flywheel:

In those waveforms diagram have been given the stator current, stator emf, rotor speed and electromagnetic torque at Steady state.

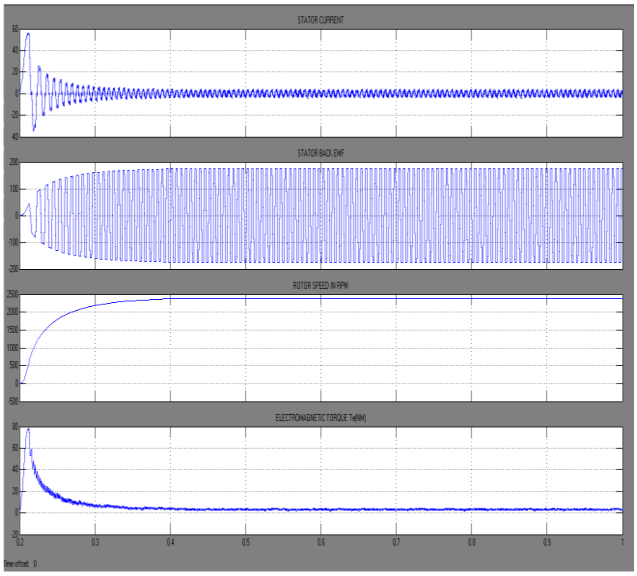

Fig.-4 Output of PMSM Stator Current, Stator Back EMF, Rotor Speed and Te

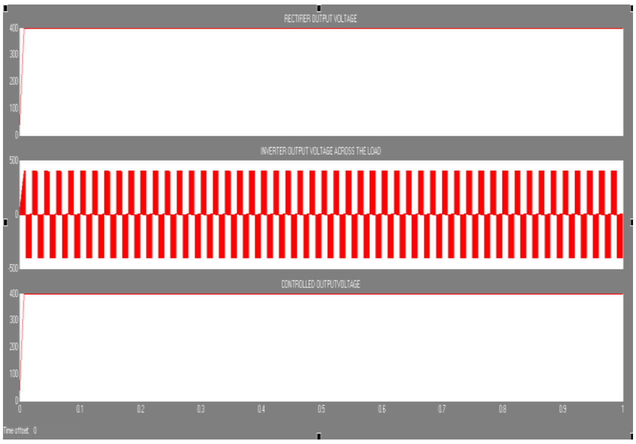

Fig – 5 Output Parameter of Rectifier controlled voltage and Inverter

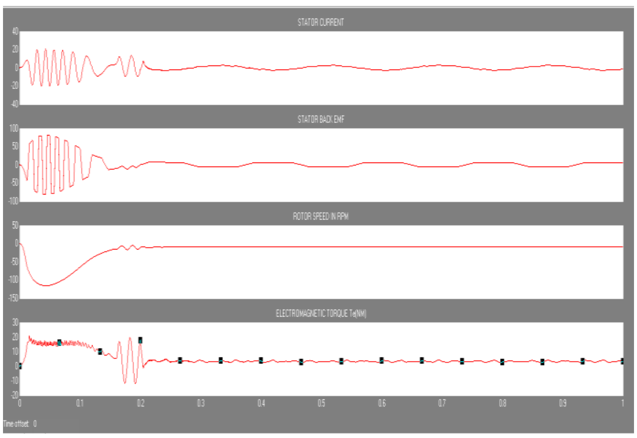

Fig – 6 Output Parameters of Flywheel

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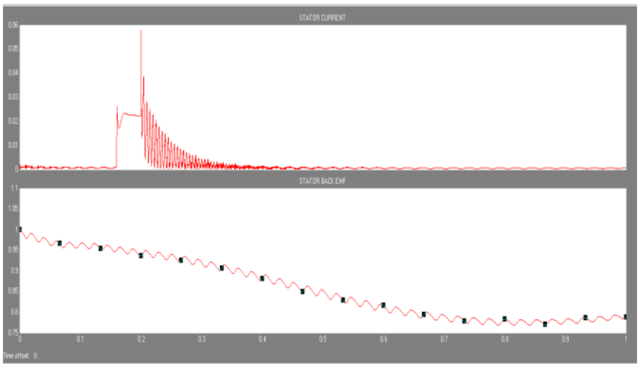

Fig -7 Diesel Generator Output

FFT Analysis

Stator Current and Percentage of THD

In this waveform diagram has been given the stator current, and its THD analysis, initially its having the more spikes but gradually those are getting reduced.

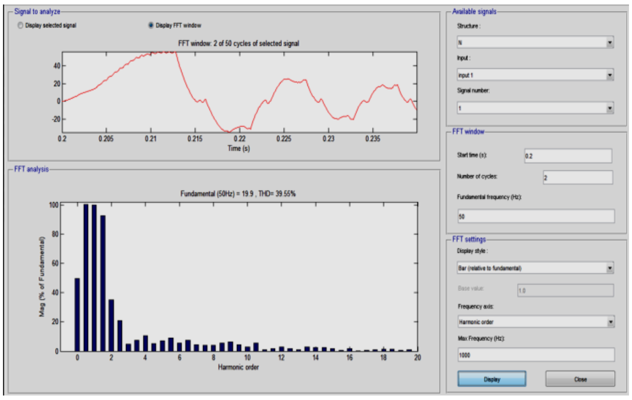

Fig. 8 Analysis of THD and Fundamental Frequency

Outputs of The 3-phase Inverter

Firing pulses for controlling the Inverter output voltage y using the pulse width modulation technique.

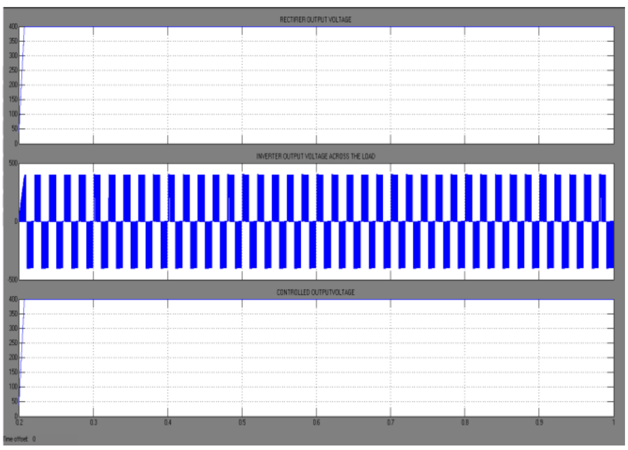

Fig.9 Outputs wave-form of the 3-phase Inverter

FFT Analysis of Rectifier output voltage and percentage of THD

In those waveforms diagram have been given the output voltage and its third harmonics distortion analysis at Steady state condition.

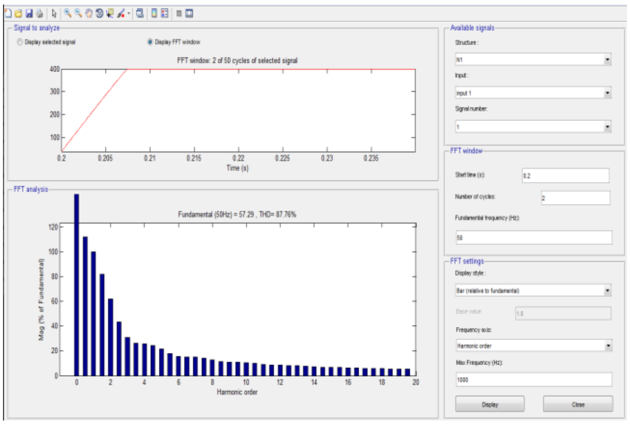

Fig.10 FFT analysis of Rectifier output voltage and percentage of THD

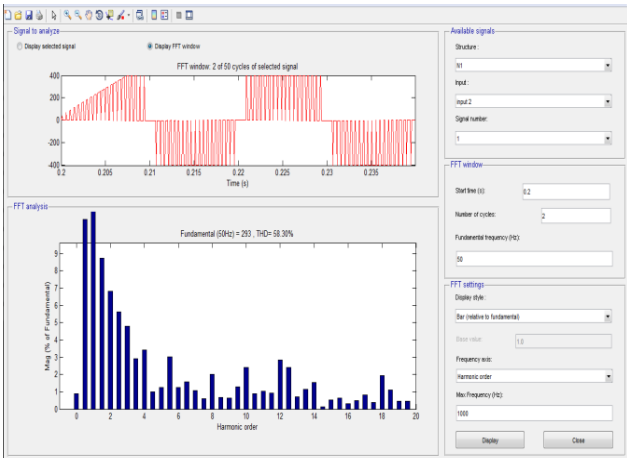

Fig. 11 FFT analysis of Inverter output voltage across the load and percentage of THD

Output of the Flywheel/Generator

In those waveforms have been given the stator current, stator emf, rotor speed and electromagnetic torque are gradually getting the steady state condition.

FFT Analysis of Inverter output voltage across the load and percentage of THD

In this waveform diagram have been given the output voltage across the load and its third harmonics distortion analysis are Steady state condition.

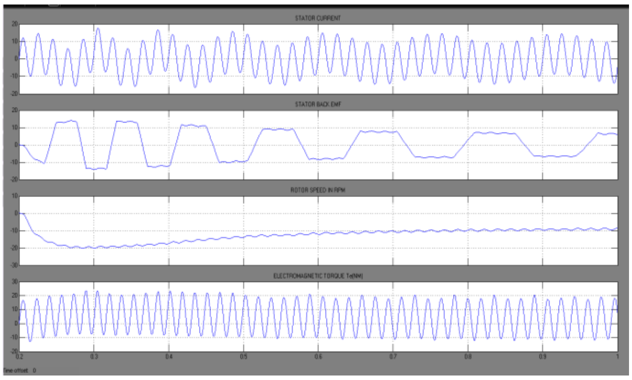

Fig.12 Output of the Flywheel/Generator

FFT Analysis of flywheel/generator stator current and percentage of THD

In this waveform diagram have been given the stator current and its third harmonics distortion analysis are at Steady state condition.

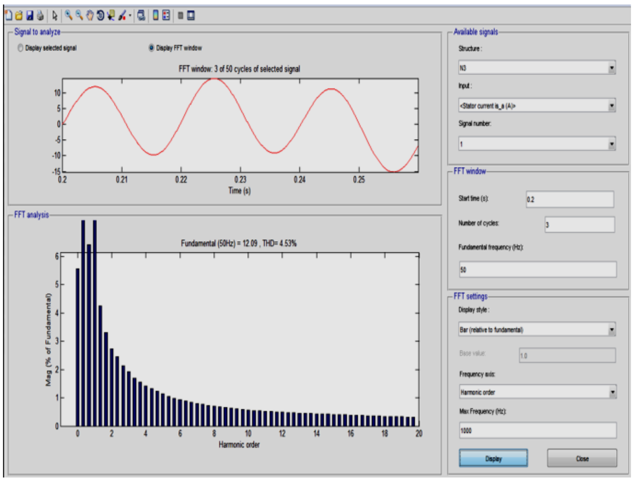

Fig-13 FFT Analysis of flywheel/generator stator current and percentage of THD

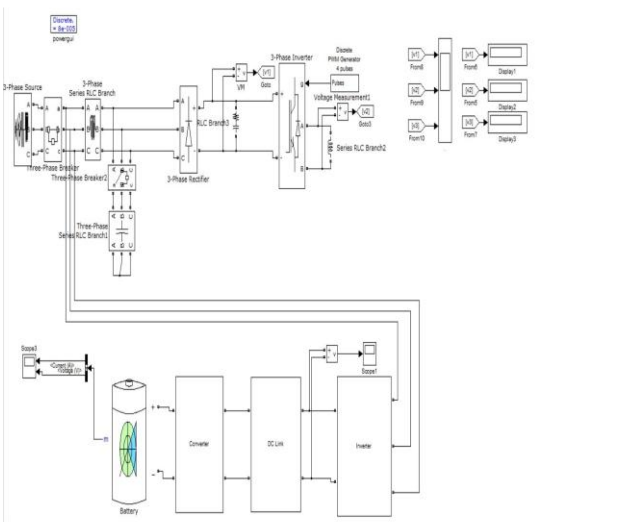

Fig-14 Proposed system with Battery backup

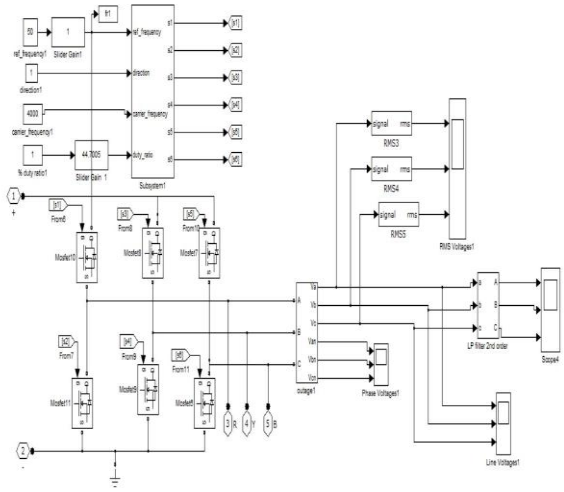

Fig- 15 Battery backup controlling system

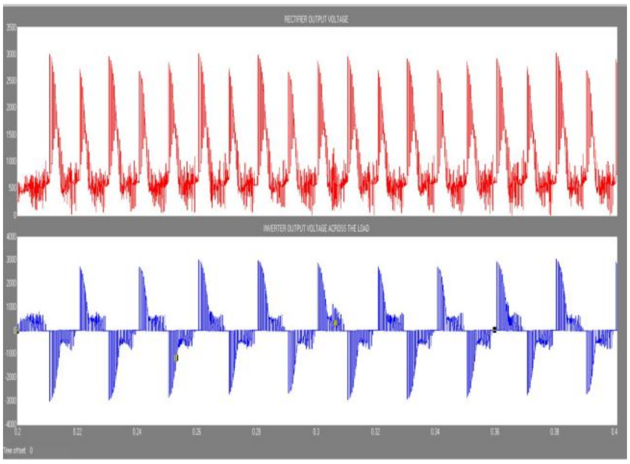

Fig-16 Rectifier and Inverter output

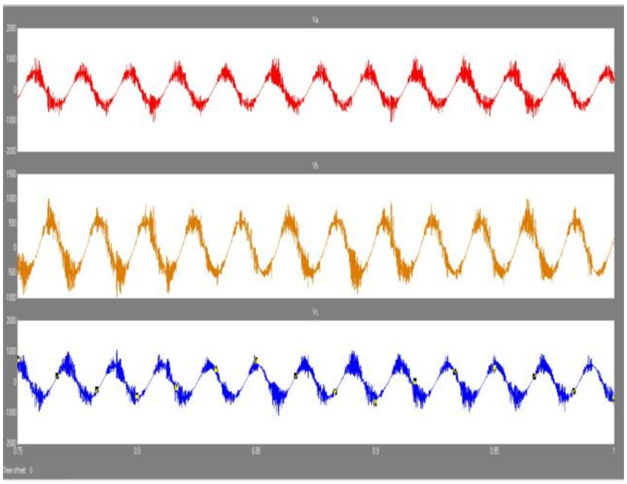

Fig-17 Line Voltage of Inverter

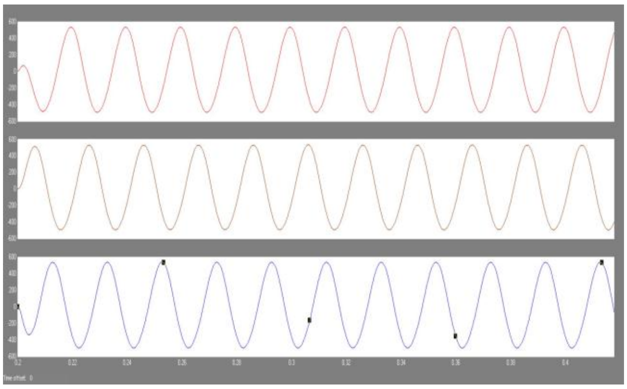

Fig-18 Phase Voltage of Inverter

IV. CONCLUSION

In this project, we have discussed the flywheel energy storage system (FESS) along with the battery storage. The system basically includes a two way energy flow scheme so that energy is injected into the flywheel in the form of kinetic energy, and drawn from the machine driving the flywheel in the form of electric energy. After showing the block diagram for our system providing some general system description, we have presented alternatives for all the components that are needed to build the FESS. Advantages and disadvantages of these alternatives have been discussed, and then the components required were chosen depending on their availability, performance, cost and reliability. Then we modeled our design using SIMULINK, and simulated it in order to verify the results. As far as the THD analysis and the energy density are concerned the simulation results from battery storage was good enough as compared to flywheel .The obtained results from both the backups were very close to the anticipated ones, and our design model is thus verified.

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