Vikas Shrivastava. Int. Journal of Engineering Research and Application *www.ijera.com*
ISSN: 2248-9622, Vol. 7, Issue 11, (Part -3) November 2017, pp.16-21

RESEARCH ARTICLE OPEN ACCESS

Research on Structure for Flywheel Energy Storage System in Long Lifetime UPS

Vikas Shrivastava,
India
Corresponding Author: Vikas Shrivastava,

ABSTRACT
This paper establishes the flywheel energy storage organization (FESS) in a long lifetime uninterruptible power supply. The Flywheel Energy Storage (FES) system has emerged as one of the best options. This paper presents a conceptual study and illustrations of FES units. After brief introduction to the FES system and its theory of operation, the paper focuses on the important role of the FES system in enhancing the operation of the distribution network. Supported by illustrated circuits, the FES system in the improvement of the power quality of the network. A flywheel energy storage technology was ended, with a special focus on the progress in automotive applications. In order to improve the efficiency and lifetime, then it discusses a newly proposed design of the FES system that emerged recently, which includes the use of Superconducting Magnetic Bearings (SMB) and Permanent Magnetic Bearings (PMB). In conclusion, the paper analyzes the FES systems great potentials that could be exploited in improving the reliability of the electrical system.

Keywords: Energy storage; Flywheel; bearings, power system quality, power system reliability, design of flywheel

---

Date of Submission: 30-10-2017 Date of acceptance: 14-11-2017

I. INTRODUCTION

Flywheel energy storage systems (FESS) store electric energy in terms of the kinetic energy of a rotating flywheel, and convert this kinetic energy into electric energy when necessary. A FESS is a viable technology for energy storage because it is environmentally safe, can sustain infinite charge/discharge cycles, and has higher power-to-weight ratio than chemical batteries [1]. FESSs commonly use active magnetic bearings (AMBs) for contact-free operation to maximize the efficiency of the system the most important trade-off'sin a flywheel energy storage system is between high power or high energy. A high-power application is relatively simple seen from a flywheel design perspective. A standard high-power electric machine is fitted with some extra weight to sustain the power for a long enough time. A focus on high energy means that therequirements on the mechanical properties of the rotor put limits on the power transfer units or suspension. Energy requirements on the mechanical properties of the rotor put limits on the power transfer units or suspension. Energy flywheels are a main area of research, since this opens uppossibilitiesfor new end applications.TheUPS necessitatethe energy buffer such as electric doublecapacitors (EDLCs), batteries, or flywheels as the UPS has to supply the power to load until an emergency generator begin. Table I shows the description of each every energy storage strategy. The battery can accomplish a high energy density at low cost. though, one of the trouble in the battery energy storage is the short life time. In meticulous, the lifetime taking place the ambient and the number of charge and discharge time. In addition, the battery cannot manage with speedy charge and discharge owing to the large internal resistance inthe battery. On the other hand, an EDLC has a high charge and discharge efficiency. Besides, the rapid charge and discharge are probable because the internal resistance is extremely small. Though, similar to the battery, the lifetime is decreased rapidly owing to the authority of the ambient temperature [1]. On the other hand, flywheel energy storage systems (FESS) has subsequent advantages compared to chemical batteries
(i) Environmental friendly,
(ii) Low maintenance cost,
(iii) Long lifetime due to no chemical structure, and
(iv) The charge and discharge characteristic of high cycle are excellent. For these reason, the flywheel has attracted attention as an energy storage system [2-8].

Table: 1 CharacteristicOf Each Storage Devices.

	Flywheel	EDLC	Battery
Energy storage Ion	Kinetic energy	Ion transfer	Chemical reaction
Charge & Discharge of short period	Fast	Fast	slow
Temperature characteristic	Excellent	Limited by temperature	Limited by temperature
Energy density	good	good	Excellent

The flywheel motor of FESS is becoming large power capacity. For quick charge and discharge, and compactness of structure, the rotor of flywheel is mounted onto the flywheel body. The gap between rotor and stator is relatively large, so the vibration of the rotor axle centre will affect the electromagnetic field parameters. On the contrary, the change of the electromagnetic field parameters will affect the dynamic characteristics of the rotor. As a result, the electromechanical coupling vibration will occur for the interaction of electromagnetic and mechanical parameters of the FESS, and will furthermore affect the rotor dynamic performance, and bring self-excited vibration. We can say that the electromechanical coupling vibration not only decreases the system stability, but also leads to disastrous accidents. In addition, there are many other features that make flywheel storage systems a promising solution for future energy needs. These features include pollution-free operation with a maximum amount of stored energy, which is mainly affected by the weight and shape of the rotor, and the high efficiency of the storage process including the efficiency of the energy conversion Based on the extended

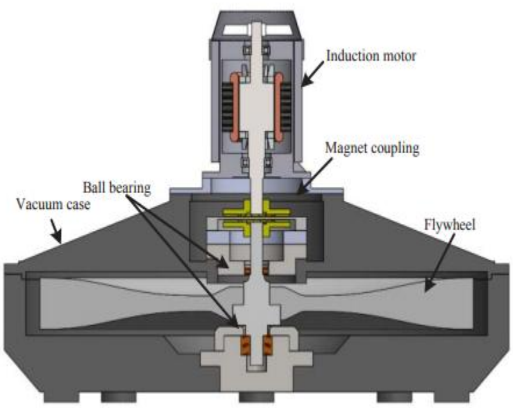


Fig.1 Configuration of a flywheel system that employs an induction motor and ball bearings

II. PRINCIPLE OF OPERATION

A flywheel stores energy in a rotating mass. Depending on the inertia and speed of the rotating mass, a given amount of kinetic energy is stored as rotational energy. The main idea is that the flywheel is placed inside a vacuum containment to eliminate any frictionless that might be caused by the air and suspended by bearings for stable operation. Then, depending on the need of the grid, the kinetic energy is transferred either in or out of the flywheel which is connected to a machine that works as either the motor or generator. In the motor mode, electric energy supplied to the stator winding is converted into torque and applied to the rotor, causing it to spin faster and thus gaining kinetic energy. While in the generator mode, the kinetic energy stored in the rotor would apply torque which is converted to the needed amount of electric energy. Fig. 1 shows the basic layout.

III. CONSTRUCTION OF FLYWHEEL ENERGY STORAGE SYSTEM

Fig. 1 shows the configuration of the first prototype FESS that employs a general induction motor and ball bearings. In this system, it is possible to store the kinetic energy of 3.0 MJ at 2900 r/min. The typical ball bearing and the general purpose motor can be applied in such low rotation speed region. In addition, the flywheel vacuum case and the motor are separated by the magnetic coupling. As a result, the windage loss can be greatly reduced because it is possible to reduce the pressure in a vacuum case by the vacuum pump. Moreover, the vacuum in the vacuum case does not affect the heat dissipation of the motor because the motor and the vacuum case are separated. Therefore, the general purpose motor can be applied to drive the flywheel without adding special cooling mechanism. Fig. 2 shows the block diagram of the flywheel system including the measurement system and auxiliary devices. In the flywheel system, the induction motor is operated as a generator during deceleration; the kinetic energy is converted into the electrical energy. On the other hand, during acceleration, the electrical energy is stored as the kinetic energy. Therefore, this system uses a regenerative converter. Furthermore, an overtemperature of the bearing and the motor can be prevented by the oil cooler.

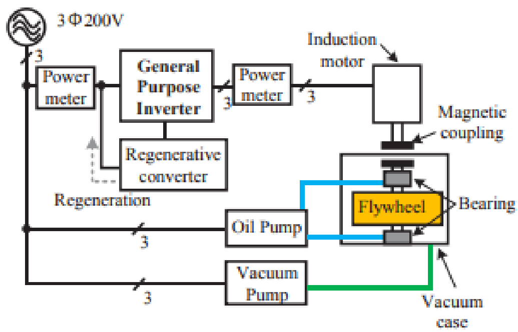


Fig.2 Block diagram of the flywheel system including the measurement system and the auxiliary devices

IV. FLYWHEEL TECHNICAL CONSIDERATIONS

According to Boland (2007) the concept of having the kinetic energy stored in a spinning mass is not a new one. A great deal of research has been conducted on this topic over several decades, specifically focusing on the flywheel units and the methods to improve their efficiency and means of operation [3]. The following aspects have always been associated with the design and work of any flywheel energy system: high-Speed Permanent Magnet Motor Generator.

The VDC systems' motor generator design utilizes specialized rare earth magnets to minimize rotor heating and maximize efficiency and reliability. This type of motor design allows the system to cycle quickly without overheating and can therefore be used in difficult applications with high cycling and long life requirements. The motor generator is rotated at speeds up to 36,750 RPM, where the flywheel system is at a fully charged state. During discharge, the rotor speed decreases to a minimum speed, typically 10,000-12,000 RPM. This speed range is called the discharge range and can be adjusted for more energy or higher cycling depending on the application. The rotor assembly of the flywheel operates in a vacuum provided by an external pump. By removing air from the rotating area of the motor, all wind age losses from the system are eliminated, increasing electrical efficiency.

A- MAGNETIC BEARINGS AND CONTROLS

Magnetic bearings allow the motor assembly to rotate at very high speeds with no physical contact to stationary components, thereby taking advantage of the high efficiencies obtainable with high-speed rotation.Magnetic bearings levitate the rotating assembly through the force of a magnetic field, and the upper and lower magnetic bearings provide five axes of support, which include the axial and radial support. The VYCON magnetic bearing design is based on a combination of permanent magnets, which provides a bias field in the gap, and controlled electromagnets, which provide the adjustment and centering of the rotor assembly. To minimize bearing power requirements and losses, the flywheel is vertically oriented, thereby only requiring the axial bearing axes to support the full rotor weight. The position of the rotor assembly is controlled by the magnetic bearing controller (MBC), which feeds rotor position information from position sensors next to the magnetic bearing actuator.

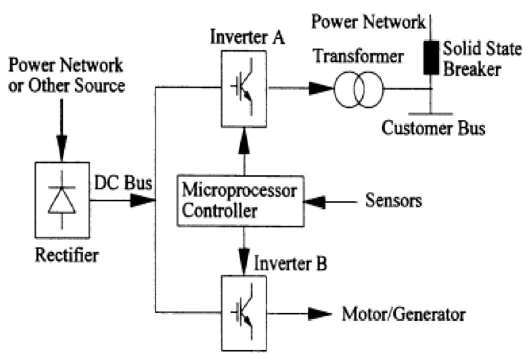
The MBC contains a digital controller, sensor inputs and current amplifiers that monitor and control the position of the flywheel rotor via a five axes active magnetic bearing system. The controller in turn adjusts the current into each coil to reposition the rotor within an allowable orbit. The rotor position signals are fed to the control module, which runs a digital filter compensation program to produce a command signal for each current amplifier. The current amplifiers provide the drive current to the actuators of each axis, thereby applying the forces on the rotor that maintains the desired flywheel rotor position. The patented magnetic bearing technology eliminates virtually all maintenance, including the need to replace or repack lubricant for a mechanical bearing system. As a result, VDC energy storage systems have a 20-year life with no bearing maintenance.

B -BI-DIRECTIONAL POWER CONVERTER

The power module is an Insulated Gat Bipolar Transistor based bi-directional direct current (DC) to alternating current (AC) or AC to DC device. During the charging or motoring state, it acts like Uninterruptible Power Source (UPS) inverter, and the power module converts DC from the UPS to 3-phase AC that is applied to the stator and spins the flywheel. While it is discharging or generating, it acts like a UPS rectifier; the power module converts the 3-phase AC from the flywheel motor-generator to a regulated DC.

C-POWER ELECTRONICS

The energy conversion in a FESS is accomplished by the electrical machine and a bi-directional power converter. The power electronic converter topologies that can be used for FESS applications are DC-AC, AC-AC, and AC-DC-AC, or a combination of these. The switching devices of the power converters are selected based on their operational characteristics and application. These include a bipolar junction transistor (BJT), metal oxide semiconductor field effect transistor (MOSFET), insulated gate bipolar transistor (IGBT), and thyristor (SCR, GTO, MCT) The commonly used switches are a silicon controlled rectifier (SCR), gate turn off thyristor (GTO), and IGBT. SCR and GTO have been traditionally used for variable frequency power converters. However, IGBT has been greatly adopted in recent years, due to its higher power capability and higher switching frequencies [9]



.Fig.3 The switching devices of the power converters

V. BASIC DESIGN APPROACH

There are two approaches in designing a flywheel unit: The first stage is to obtain the amount of energy• required for the desired degree of smoothing in addition to the moment of inertia needed to absorb that determined energy. The second stage is to define the flywheel• geometry, which caters to the required moment of inertia in a reasonably sized package. A. Design Parameters There are many parameters to be considered in the design of the flywheel energy unit: 1) Speed fluctuation the speed fluctuation is defined as the change in the shaft speed during a cycle, given by the following equation:

Fl = W max − $Wmin$ ....(i)

Coefficient of speed fluctuation.

The coefficient of speed fluctuation is one of the parameters set by the designer. The smaller this chosen value, the larger the flywheel would be and the greater the cost and weight to be added to the system. However the smaller coefficient would result in the smoother operation of the flywheel energy unit. The coefficient can be found by the following equation:

Cf = W max −$Wmin$ /W (ii)

Where$W$: the nominal angular velocity.

The typical value of Cf is set to be between 0.01 up to 0.05 for precision machinery work. 3) Design equations The kinetic energy in a rotating machine is given by

Ek= ½ I w 2 iii

The kinetic energy in any system could thus be found from

Ek = E1 – E2

Ek= ½ Is (2wavg) (Cfwavg) iv

E1 – E2 = Cf Iw2

The above equation can also be used to obtain an appropriate flywheel inertia Im corresponding to the known energy exchange Ek at a specific value of coefficient Cf .

A- FLYWHEEL ENERGY DESIGN USING SMB AND PMB

The Flywheel energy storage approach is currently considered as one of the most successful figures of energy storage, and many attempts have been made to improve this technology. Among these latest developments is the use of a superconducting magnetic bearing (SMB) together with a permanent magnetic bearing (PMB). According to Komori (2011) this approach has resulted in higher energy storage compared with conventional flywheel systems, and would lead to reduced overall costs and cooling costs. One of the main issues in operating the flywheel system is the large vibration transmitted to the rotor during operation, causing difficulties in controlling the speed of the rotation. The purpose of this specific design, using SMB and PMB, is to support the rotor in the flywheel system; the main function of the SMB is to suppress the vibrations in the rotor, while the PMB passively controls and maintains the position of the rotor [7]. 1)

B-DESCRIPTION OF THE DESIGN

Fig. 4 shows a schematic description of the flywheel energy storage system using a SMB and a PMB. It should be noted that the SMB is placed into the bottom of the system's rotor, while the PMB is set at the top of the flywheel rotor. This is because the damping effect of the SMB is effective if it is placed in the lower side of the rotor, while PMB has no damping effect [8]. The flywheel is constructed so that the centre of gravity is lower than the centre of the supporting point. Thus, the centre of gravity still lies in the centre position of the upper magnet of the SMB part, which would give the system more inertia and make it more stable under both rotating and non-rotating condition [7].

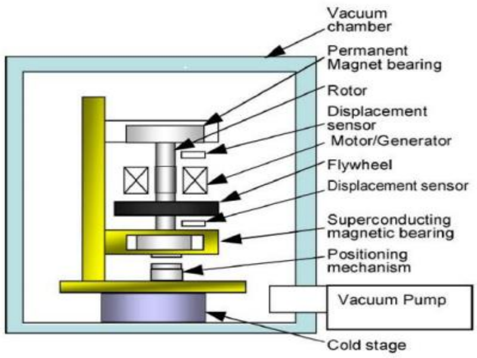


Fig. 4 Shows a schematic description of the flywheel energy storage system using a SMB and a PMB

VI. THE LATEST DEVELOPMENT OF THE MOTOR/GENERATOR FOR THE FES SYSTEM

2016 :Yali the Motor/Generator is the core dynamic component for the FES system. So far, except for very few applications of special or new structure motors such as synchronous homopolar machines, disc-type motors, printed circuit windings, three types of motors have been widely used, including the Induction Motor, the RM and the PMM [11]. A. Induction Motor/Generator (IM/G) 1996: Researchers in Japan developed a 0.2kWh,• 16500rpm FES device with IM/G, which first used high strength carbon fiber for the flywheel and was capable of preferable stability at high speed. In August of 1996, a 5500kWh, 74,000kg, 4m diameter FES system which used a doubly-fed IM/G rated 26.5MVA, with 12 poles and 90% for line frequency regulation on a 132kV bus was installed and commissioned at the Chujowansubstation .

2015 Okinawa Electric Power Company in Japan. :Roberto Ardenas of the University of•Magallancesin Chile introduced an IM/G for FES system with the following ratings: 2.5kW, 380V, 7A, 28/4 (slots/poles), rated speed of 1460 rpm and rotational inertia of 1.8kgm2. 2009: The Integrated Research Institute of Tokyo• and the Institute of Technology collaborated with the Fuji Electric Device Technology Corporation to develop an 11kW IM/G for 61Wh, 700kg, out diameter of 200mm and axial length of 135mm FES system which could be apply to voltage sag compensator and UPS power source.

2006: B. Reluctance Motor/Generator (RM/G) Roberto Ardenas of University of• Magallanes in Chile researched a 1, 000rpm-2, 000 rpm FES system for power smoothing using a 2.5kW, 8/6, 0.9 switched RM, it was the first experimental implementation to the RM flywheel system for power smoothing applications. 2008: Pentadyne Power Corporation of Los• Angeles manufactured an FES system using a 120kW, 4 poles and 25,000-54,000rpm synchronous RM for UPS application. With DSP controller and three-phase inverter, the system realized of rectifier and stability by a model based feed forward controller and a PI feedback compensator.

2010: Pentadyne Power Corporation of Los Angeles developed a carbon fiber flywheel of GTX for UPS, and with a 200kW, 350V–590V (DC voltage), 400A of short time current, weight 590kg, 4 poles synchronous RM/G in a vacuum, the prototype as shown in Fig. 3. Stator cooled in liquid. Synchronous RM provided constant power output for DC bus. C. Permanent Magnet Motor/Generator (PMM/G) 1) PMM/G with the traditional structure

2012: Researchers at University of Michigan conducted the control method of 32kW, 2 poles PMM/G for electric and hybrid electric vehicles FES system, and proposed an advanced optimal control scheme, which had the good performance to maximize power density and minimize machine size and weight.

2011: Paulo Gamboa of institute Superior de-Engenharia de Lisboa in Portugal designed a 30Wh, 2,500rpm FES system. It was applied to dynamic voltage restorer to mitigate voltage sags and prevented the voltage ripple in power system. PMM/G parameters were: charge power of 2.9kW, maximum speed of 3,000rpm and rotational inertia of 4.2kgm2 , discharge power 200kW in time 0.5S, torque constant 1.39Nm/A.

2009: Yu Li of Nanjing University of Information• Science & Technology in China applied 2D FEA to design a 20,000rpm, 6/4 high speed PMM/G for a FES system. The stator outer diameter was 60mm, maximum voltage was 110V, and efficiency was 82%. The model had been optimal redesigned aiming at deducing the iron loss, and it was valid has been proved by the results. International Journal of Electrical Energy, Halbach structure PMM/G

2002: Power System Laboraty of Korea and Electric Power Research Institute cooperated with Korea Electric Power Corporation to develop a 300W FES system with Superconducting magnetic bearing and high efficiency coreless 4 poles Halbach structure PMM/G, the rotor outer diameter was 44mm, stator inner diameter was 53mm. The FES system with a horizontal axle mounted can run smoothly up to 20,000rpm in a vacuum. The coreless Halbach structure M/G was effective on transferring electrical energy to the rotating composite flywheel in the kinetic forms.

2008: A research conducted at Chungnam National University of Korea on a 5kWh, 215kg, FES system project. A 30kW class Halbach PMM/G with double-sided rotor and coreless three-phase winding stator has been analyzed for rotor magnetization and stator winding current. The torque was 14.3N at 20,000rpm, maximum voltage of output inverter was 350V, sine pulse width modulation current was 64A. Results showed that the dynamic Halbach PMM/G for the FES system was efficient even for a heavy flywheel, also can run in constant speed for a long time

VII. CONCLUSION

Flywheel storage energy system is not a new technology; though, the bottomless interest in applying its principle in power system applications has been really increasing in the recent decades. in addition, research has been applied to develop the great feature the FES can offer, which primarily exposed in power excellence improvement and improvement of the network dependability and stability. in addition, advancements in the design of the flywheel energy units, composite materials, and power electronics devices have powerfully presented the FES technology as vulnerable option to the electromechanical batteries, especially that FES system have the description of storing and releasing energy in very fast time with very high operational efficiency. Besides, Flywheels are now used intensively in many applications related to power system such as telecommunications, utilities load levelling, and even in some additional applications in satellite engineering as well. In addition, it has been concentrated lately in distribution sectors of electrical power. Most of the distribution networks are exposed to voltage dips problems, and FES system, associated with its power electronics converters, offer effective compensation for the network Moreover, many researchers have started conducting studies to evaluate the high possibility of having FES systems with intermittent power system sources such as wind and solar systems .This paper tried to demonstrate the concept of many technical papers on FES system. After illustrating the basic functioning design and way of work, this paper described the position of the FES systems in the control of reactive power and power quality in distribution network. behind that, a brief basic design and lately design of flywheels using SMB and PMB have been illustrated in some feature. The paper concluded with the recent developments in flywheels industry that can offer the FES systems in the future to be great solution to solve the power system reliability problems in the lowvoltage distribution network.

REFERENCES

[1] T. Aanstoos, J. P. Kajs, W. Brinkman, H. P. Liu, A. Ouroua, and R. J. Hayes, "High voltage stator for a flywheel energy storage system," IEEE Trans. Magazine, vol. 37, no. 1, pp. 242-247, 2015.

[2] I. Vajed, Z. Kohari, L. Benko, V. Meerovich, and W. Gawalek, "Investigation of joint operation of a superconducting kinetic energy storage (Flywheel) and solar cells," IEEE Transactions on Applied Superconductivity, vol. 13, no. 2, Jun. 2013.

[3] B. Bolund, H. Bernhoff, and M. Leijon, "Flywheel energy and power storage System," Renewable and Sustainable Energy Reviews, vol. 11, no. 2, pp. 235-258, 2007.

[4] J. C. Zhang, L. P. Huang, Z. Y. Chen, and S. Wu, "Research on flywheel energy storage system for power quality," in Proc. International Conference on Power System Technology, 2002, pp. 496-499.

[5] J. C. Zhang, Z. Y. Chen, L. J. Cai, and Y. H. Zhao, "Flywheel energy storage system design for distribution network," in Proc. IEEE Power Engineering Society Winter Meeting, 2000, pp. 2619-2623.

[6] A. Al-Diab and C. Sourkounis, "Integration of flywheel energy storage system in production lines for voltage drop compensation," in Proc. 37th Annual Conference on IEEE Industrial Electronics Society, Melbourne, VIC, 2011, pp. 3882- 3887.

[7] M. Subkhan and M. Komori, "New concept for flywheel energy storage system using SMB and PMB," IEEE Transactions on Applied Superconductivity, vol. 21, no. 3, Jun. 2011. International Journal of Electrical Energy, Vol. 2, No. 2, June 2014 ©2014 Engineering and Technology Publishing 152 International Journal of Electrical Energy, Vol. 2, No. 2, June 2014 ©2014 Engineering and Technology Publishing 153

[8] K. Murakami, M. Komori, and H. Mitsuda, "Flywheel energy storage system using SMB and PMB," IEEE Transactions on Applied Superconductivity, vol. 17, no. 2, Jun. 2007.

[9] H. Mitsuda, M. Komori, A. Inoue, and B. Nakaya, "Improvement of energy storage flywheel system with SMB and PMB and its performances," IEEE Transactions on Applied Superconductivity, vol. 19, no. 3, Jun. 2009. [10] Beacon Power, Response to the New York Energy Highway Request for Information (RFI), May 30th , 2012. Official Report.

[10] Y. L. Yu, Y. X. Wang, and F. Sun, "The latest development of the motor/generator for the flywheel energy storage system," in Proc. International Conference on Mechatronic Science, Electric Engineering and Computer (MEC), Jilin, 2011, pp. 1228-1232.

[11] Y. L. Yu, Y. X. Wang, and F. Sun, "Dynamic voltage compensation on distribution feeders using flywheel energy storage," IEEE Transactions on Power Delivery, vol. 14, no. 2, Apr. 1999.

International Journal of Engineering Research and Applications (IJERA) is **UGC approved** Journal with Sl. No. 4525, Journal no. 47088. Indexed in Cross Ref, Index Copernicus (ICV 80.82), NASA, Ads, Researcher Id Thomson Reuters, DOAJ.

Vikas Shrivastava Research onStructure for Flywheel Energy Storage System in Long Lifetime UPS." International Journal of Engineering Research and Applications (IJERA) , vol. 7, no. 11, 2017, pp. 16-21.