

Regenerative Braking Systems (RBS) (Future of Braking Systems)

J. Manikandan and M. Akash

Abstract--- Presently what the world needs is a method or a technology that saves energy from getting wasted. Energy conservation is the hour of need. In case of automobiles, energy conservation can be done by using regenerative braking systems (RBS). When driving an automobile, a great amount of kinetic energy is wasted when brakes are applied, which then makes the start up fairly energy consuming. The main aim of this project was to develop a product that stores the energy which is normally lost during braking, and reuses it. The use of regenerative braking system in automobiles provides us the means to balance the kinetic energy of the vehicle to some extent which is lost during the process of braking. The authors of the paper have discussed and presented two methods of using the kinetic energy which generally gets wasted by converting it into either mechanical energy or into electrical energy. Flywheel is used for converting the kinetic energy to mechanical energy. Also, Electric Motor is used to convert Kinetic Energy into electrical energy.

Keywords--- Regenerative Braking Mechanism, Electric Motor, Flywheel.

I. INTRODUCTION

A. Conventional Braking Systems in Automobiles: The term 'Braking' in a moving vehicle means the application of the brakes to reduce its speed or stop its movement, usually by depressing a pedal. The braking distance is the distance between the time the brakes are applied and the time the vehicle comes to a complete stop. In braking systems on conventional vehicles, friction is used to counteract the forward momentum of a moving vehicle. As the brake pads rub against the wheels or a disc that is connected to the axles, excessive heat energy is created. This heat energy dissipates into the air, wasting as much as 30 percent of the vehicle's generated power. Over time, this cycle of friction and wasted heat energy reduces the vehicle's fuel efficiency. More energy from the engine is required to replace the energy that was lost by braking.

Slows down, the kinetic energy that was propelling it in the forward direction has to go somewhere. Most of it simply gets released in the form of heat and becomes useless. That energy, which could have been used to do work, is essentially wasted. The solution for this kind of this problem is Regenerative Braking System. This is a new type of braking system that can recollect much of the car's kinetic energy and convert it into electrical energy or mechanical energy. Regenerative braking is one of the emerging technologies of automotive industry which can prove to be very beneficent. Using regenerative braking system in a vehicle not only results in the recovery of the energy but it also increases the efficiency of vehicle(in case of hybrid vehicles) and saves energy, which is stored in the auxiliary battery.

J. Manikandan, Assistant Professor, Department of Mechanical Engineering, BIST, BIHER, Bharath Institute of Higher Education & Research, Selaiyur, Chennai. E-mail: kandan.arni@gmail.com

M. Akash, UG Scholar, Department of Mechanical Engineering, BIST, BIHER, Bharath Institute of Higher Education & Research, Selaiyur, Chennai. E-mail: akashm9699@gmail.com

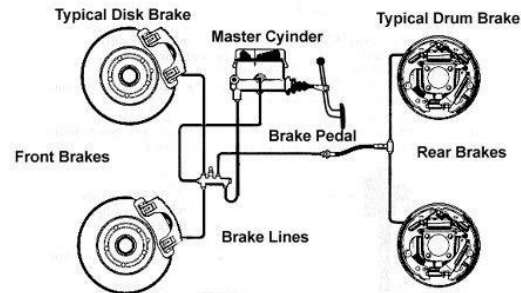


Fig.1: Conventional Braking System in Four Wheeler

B. Regenerative Braking Systems in Automobiles: Every time we step on our car's brakes, we are actually wasting energy. As we know that energy can neither be created nor be destroyed. It can be just converted from one form to another. So when our car.

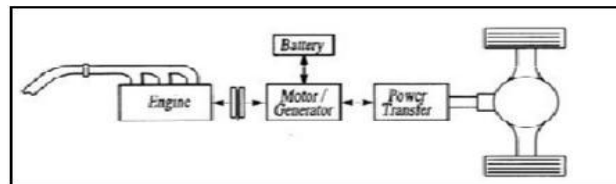


Fig.2: Simple Regenerative Braking System

Driving an automobile involves many braking events, due to which higher energy losses takes place, with greater potential savings. With buses, taxis, delivery vans and so on there is even more potential for economy. As we know that the regenerative braking, the efficiency is improved as it results in an increase in energy output for a given energy input to a vehicle. The amount of work done by the brake engine of the vehicle is reduced, in turn reducing the amount of energy required to drive the vehicle.

Mechanical energy is converted into electrical energy and during discharging electrical energy is converted into mechanical energy. So, due to these conversions transmission losses occur and the efficiency reduces. As, in the other case, there are no transmission losses since mechanical energy stored in the flywheel is directly transferred to the vehicle in its original form. As the energy is supplied instantly and efficiency is high, these types of systems are used in F-1 cars.

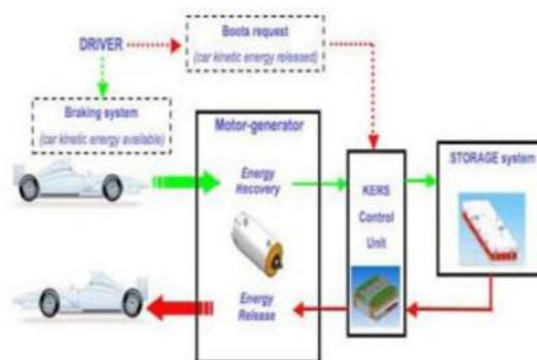


Fig.3: Block Diagram of Regenerative Braking System

This advancement of technology in braking system controls the speed of the vehicle by converting some amount of the vehicle's kinetic energy into another useful form of energy. The energy so produced can then be stored as mechanical energy in flywheels, or as, electrical energy in the automobile battery, which can be used again by the vehicle.

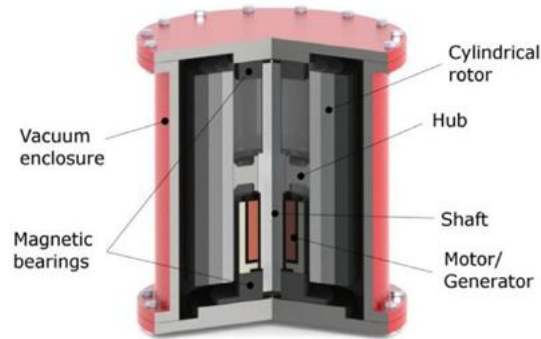


Fig.4: The main components of a typical flywheel

A regenerative brake is an energy recovery mechanism which slows a vehicle or object down by converting its kinetic energy into another form, which can be either used immediately or stored by a short term storage system. Energy normally dissipated in the brakes is directed by a power transmission system to the auxiliary battery during deceleration. The stored energy can be converted back into kinetic energy and used whenever the vehicle is to be accelerated. The magnitude of the portion available for energy storage varies according to the type of storage, drive train efficiency, drive cycle and inertia weight. The effect of regenerative brakes is less at lower speeds as compared to that at higher speeds of vehicle. So the friction brakes are needed in a situation of regenerative brake failure, to stop the vehicle completely.

II. CONVERSION OF KINETIC ENERGY TO MECHANICAL ENERGY USING FLYWHEEL ENERGY STORAGE

A flywheel is a type of energy storage system which is used to store mechanical energy and then release the stored energy when needed for acceleration.

Flywheel is a heavy, high-speed rotating disc that builds up kinetic energy (the force that causes movement) as it spins. The amount of energy stored depends upon how heavier it is and how fast it rotates. Heavier weight and faster rotation results in higher energy storage. We can relate it to a discus thrower in the Olympics. He winds-up, building an increasing store of force and energy as he spins, and then releases the disc and sends it flying through the air. The method of transmission of energy directly to the vehicle is more efficient rather than first storing it in the battery, as it does not consist of the conversion of energies. As, during the recharging of battery,

III. CONVERSION OF KINETIC ENERGY TO ELECTRICAL ENERGY USING ELECTRIC MOTOR

The most common form of regenerative brake involves using an electric motor as an electric generator. The working of the regenerative braking system depends upon the working principle of an electric motor, which is the important component of the system. Electric motor gets activated when some electric current is passed through it.

But, when some external force is applied to activate the motor (during the braking), then it behaves as a generator and generates electricity.

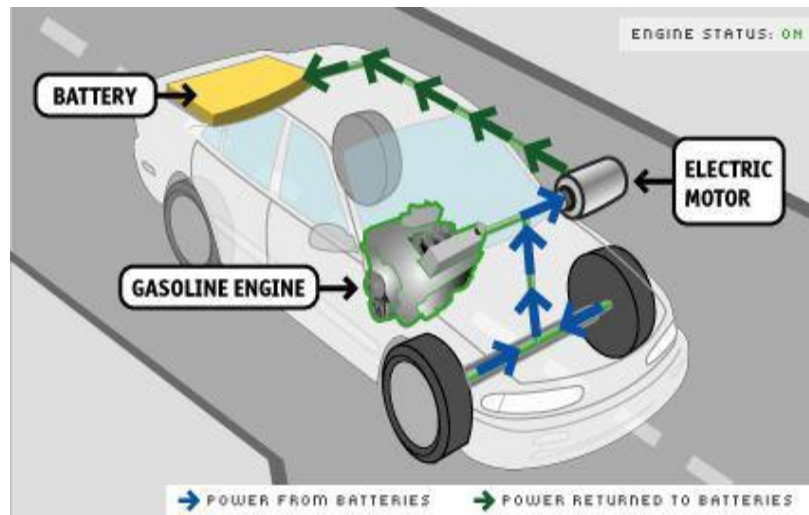


Fig.5: Energy flow diagram of a regenerative braking system

This means that whenever motor runs in one direction, the electric energy gets converted into mechanical energy, which is then used to accelerate the vehicle and whenever the motor runs in opposite direction, it performs functions of a generator, which then converts mechanical energy into electrical energy, which makes it possible to utilize the rotational force of the driving axle to turn the electric motors, which results in regenerating electric energy for storage in the battery and simultaneously reducing the speed of the car with the regenerative resistance of the electric motors. This electricity is then used for recharging the battery used in electric railway vehicle (London Underground & Virgin Trains).

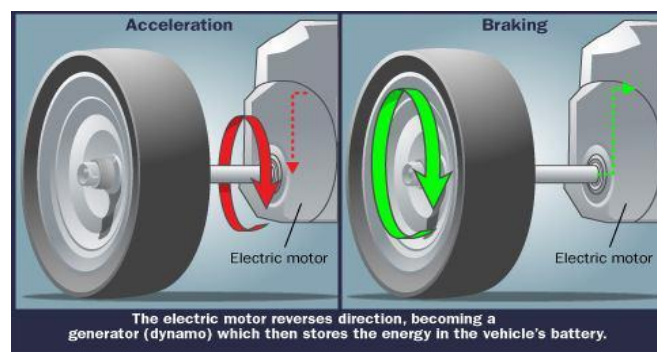


Fig.6: Operation of an Electric Motor

IV. ADVANTAGES OF REGENERATIVE BRAKING SYSTEMS

Improved Performance.

Improved Fuel Economy- Dependent on duty cycles, power train design, control strategy, and the efficiency of individual components.

Reduction in Engine wears.

Reduction in Brake Wear- Reducing cost of replacement brake linings, cost of labor to install them, and vehicle down time,

Emissions reduction- engine emissions reduced by engine decoupling, reducing total engine revolutions and total time of engine operation.

Operating range is comparable with conventional vehicles- a problem not yet overcome by electric vehicles.

V. REGENERATIVE BRAKING EFFICIENCY

The energy efficiency of a conventional car is only about 20 percent, with the remaining 80 percent of its energy being converted to heat through friction. The miraculous thing about regenerative braking is that it may be able to capture as much as half of that wasted energy and put it back to work. This could reduce fuel consumption by 10 to 25 percent. Hydraulic regenerative braking systems could provide even more impressive gains, potentially reducing fuel use by 25 to 45 percent. In a century that may see the end of the vast fossil fuel reserves that have provided us with energy for automotive and other technologies for many years, and in which fears about carbon emissions are coming to a peak, this added efficiency is becoming increasingly important.

The added efficiency of regenerative braking also means less pain at the pump, since hybrids with electric motors and regenerative brakes can travel considerably farther on a gallon of gas, some achieving more than 50 miles per gallon at this point. And that's something that most drivers can really appreciate.

VI. APPLICATIONS OF REGENERATIVE BRAKING SYSTEMS

For recovering Kinetic energy of vehicle lost during braking process.

One theoretical application of regenerative braking would be in a manufacturing plant that moves material from one workstation to another on a conveyer system that stops at each point.

Regenerative braking is used in some elevator and crane hoist motors.

Regenerative Braking Systems are also

VII. LIMITATIONS OF REGENERATIVE BRAKING SYSTEMS

The main limitation of regenerative brakes when compared with dynamic brakes is the need to closely match the electricity generated with the supply. With DC supplies this requires the voltage to be closely controlled and it is only with the development of power electronics that it has been possible with AC supplies where the supply frequency must also be matched (this mainly applies to locomotives where an AC supply is rectified for DC motors).

Regenerative braking is necessarily limited when the batteries are fully charged. Because the additional charge from regenerative braking would cause the voltage of a full battery to rise above a safe level, our motor controller will limit regenerative braking torque in this case.

Increases the total weight of vehicle by around 25-30 Kilograms.

VIII. FUTURE SCOPE

Regenerative braking systems require further research to develop a better system that captures more energy and stops faster. As the time passes, designers and engineers will perfect regenerative braking systems, so these systems will become more and more common. All vehicles in motion can benefit from these systems by recapturing energy that would have been lost during braking process.

Future technologies in regenerative brakes will include new types of motors which will be more efficient as generators, new drive train designs which will be built with regenerative braking in mind, and electric systems which will be less prone to energy losses.

Of course, problems are expected as any new technology is perfected, but few future technologies have more potential for improving vehicle efficiency than does regenerative braking.

IX. CONCLUSION

The regenerative braking system used in the vehicles satisfies the purpose of saving a part of the energy lost during braking. Also it can be operated at high temperature range and are efficient as compared to conventional braking system. The results from some of the test conducted show that around 30% of the energy delivered can be recovered by the system.

Regenerative braking system has a wide scope for further development and the energy savings. The use of more efficient systems could lead to huge savings in the economy of any country.

REFERENCES

- [1] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Virtual instrumentation based process of agriculture by automation. *Middle-East Journal of Scientific Research*, 20(12): 2604-2612.
- [2] Udayakumar, R., Kaliyamurthie, K.P., & Khanaa, T.K. (2014). Data mining a boon: Predictive system for university topper women in academia. *World Applied Sciences Journal*, 29(14): 86-90.
- [3] Anbuselvi, S., Rebecca, L.J., Kumar, M.S., & Senthilvelan, T. (2012). GC-MS study of phytochemicals in black gram using two different organic manures. *J Chem Pharm Res.*, 4, 1246-1250.
- [4] Subramanian, A.P., Jaganathan, S.K., Manikandan, A., Pandiaraj, K.N., Gomathi, N., & Supriyanto, E. (2016). Recent trends in nano-based drug delivery systems for efficient delivery of phytochemicals in chemotherapy. *RSC Advances*, 6(54), 48294-48314.
- [5] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Partial encryption and partial inference control based disclosure in effective cost cloud. *Middle-East Journal of Scientific Research*, 20(12), 2456-2459.
- [6] Lingeswaran, K., Prasad Karamcheti, S.S., Gopikrishnan, M., & Ramu, G. (2014). Preparation and characterization of chemical bath deposited cds thin film for solar cell. *Middle-East Journal of Scientific Research*, 20(7), 812-814.
- [7] Maruthamani, D., Vadivel, S., Kumaravel, M., Saravanakumar, B., Paul, B., Dhar, S.S., Manikandan, A., & Ramadoss, G. (2017). Fine cutting edge shaped Bi₂O₃rods/reduced graphene oxide (RGO) composite for supercapacitor and visible-light photocatalytic applications. *Journal of colloid and interface science*, 498, 449-459.
- [8] Gopalakrishnan, K., Sundeep Aanand, J., & Udayakumar, R. (2014). Electrical properties of doped azopolyester. *Middle-East Journal of Scientific Research*, 20(11). 1402-1412.
- [9] Subhashree, A.R., Parameaswari, P.J., Shanthi, B., Revathy, C., & Parijatham, B.O. (2012). The reference intervals for the haematological parameters in healthy adult population of chennai, southern India. *Journal of Clinical and Diagnostic Research: JCDR*, 6(10), 1675-1680.

- [10] Niranjana, U., Subramanyam, R.B.V., & Khanaa, V. (2010, September). Developing a web recommendation system based on closed sequential patterns. In *International Conference on Advances in Information and Communication Technologies, 101*, 171-179. Springer, Berlin, Heidelberg.
- [11] Slimani, Y., Baykal, A., & Manikandan, A. (2018). Effect of Cr³⁺ substitution on AC susceptibility of Ba hexaferrite nanoparticles. *Journal of Magnetism and Magnetic Materials*, 458, 204-212.
- [12] Premkumar, S., Ramu, G., Gunasekaran, S., & Baskar, D. (2014). Solar industrial process heating associated with thermal energy storage for feed water heating. *Middle East Journal of Scientific Research*, 20(11), 1686-1688.
- [13] Kumar, S.S., Karrunakaran, C.M., Rao, M.R.K., & Balasubramanian, M.P. (2011). Inhibitory effects of *Indigofera aspalathoides* on 20-methylcholanthrene-induced chemical carcinogenesis in rats. *Journal of carcinogenesis*, 10.
- [14] Beula Devamalar, P.M., Thulasi Bai, V., & Srivatsa, S.K. (2009). Design and architecture of real time web-centric tele health diabetes diagnosis expert system. *International Journal of Medical Engineering and Informatics*, 1(3), 307-317.
- [15] Ravichandran, A.T., Srinivas, J., Karthick, R., Manikandan, A., & Baykal, A. (2018). Facile combustion synthesis, structural, morphological, optical and antibacterial studies of Bi_{1-x}Al_xFeO₃ (0.0 ≤ x ≤ 0.15) nanoparticles. *Ceramics International*, 44(11), 13247-13252.
- [16] Thovhogi, N., Park, E., Manikandan, E., Maaza, M., & Gurib-Fakim, A. (2016). Physical properties of CdO nanoparticles synthesized by green chemistry via Hibiscus Sabdariffa flower extract. *Journal of Alloys and Compounds*, 655, 314-320.
- [17] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Wide area wireless networks-IETF. *Middle-East Journal of Scientific Research*, 20(12), 2042-2046.
- [18] Sundar Raj, M., Saravanan, T., & Srinivasan, V. (2014). Design of silicon-carbide based cascaded multilevel inverter. *Middle-East Journal of Scientific Research*, 20(12), 1785- 1791.
- [19] Achudhan, M., Jayakumar M.P. (2014). Mathematical modeling and control of an electrically-heated catalyst. *International Journal of Applied Engineering Research*, 9(23), 23013.
- [20] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2013). Application of pattern recognition for farsi license plate recognition. *Middle-East Journal of Scientific Research*, 18(12), 1768-1774.
- [21] Jebaraj, S., Iniyana S. (2006). Renewable energy programmes in India. *International Journal of Global Energy Issues*, 26(43528), 232-257.
- [22] Sharmila, S., & Jeyanthi Rebecca, L. (2013). Md Saduzzaman., Biodegradation of domestic effluent using different solvent extracts of *Murraya koenigii*. *J Chem and Pharm Res*, 5(2), 279-282.
- [23] Asiri, S., Sertkol, M., Guner, S., Gungunes, H., Batoo, K.M., Saleh, T.A., Manikandan A., & Baykal, A. (2018). Hydrothermal synthesis of CoyZnyMn_{1-2y}Fe₂O₄ nanoferrites: magneto-optical investigation. *Ceramics International*, 44(5), 5751-5759.
- [24] Rani, A.J., & Mythili, S.V. (2014). Study on total antioxidant status in relation to oxidative stress in type 2 diabetes mellitus. *Journal of clinical and diagnostic research: JCDR*, 8(3), 108-110.
- [25] Karthik, B. (2014). Arulselvi, Noise removal using mixtures of projected gaussian scale mixtures. *Middle-East Journal of Scientific Research*, 20(12), 2335-2340.
- [26] Karthik, B., Arulselvi, & Selvaraj, A. (2014). Test data compression architecture for low power VLSI testing. *Middle - East Journal of Scientific Research*, 20(12), 2331-2334.
- [27] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). Privacy conscious screening framework for frequently moving objects. *Middle-East Journal of Scientific Research*, 20(8), 1000-1005.
- [28] Kaliyamurthi, K.P., Parameswari, D., & Udayakumar, R. (2013). QOS aware privacy preserving location monitoring in wireless sensor network. *Indian Journal of Science and Technology*, 6(5), 4648-4652.
- [29] Silambarasu, A., Manikandan, A., & Balakrishnan, K. (2017). Room-temperature superparamagnetism and enhanced photocatalytic activity of magnetically reusable spinel ZnFe₂O₄ nanocatalysts. *Journal of Superconductivity and Novel Magnetism*, 30(9), 2631-2640.
- [30] Jasmin, M., Vigneshwaran, T., & Beulah Hemalatha, S. (2015). Design of power aware on chip embedded memory based FSM encoding in FPGA. *International Journal of Applied Engineering Research*, 10(2), 4487-4496.

- [31] Philomina, S., & Karthik, B. (2014). Wi-Fi energy meter implementation using embedded linux in ARM 9. *Middle-East Journal of Scientific Research*, 20, 2434-2438.
- [32] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). A DFIG based wind generation system with unbalanced stator and grid condition. *Middle-East Journal of Scientific Research*, 20(8), 913-917.
- [33] Rajakumari, S.B., & Nalini, C. (2014). An efficient data mining dataset preparation using aggregation in relational database. *Indian Journal of Science and Technology*, 7, 44-46.
- [34] Karthik, B., Kiran Kumar, T.V.U., Vijayaragavan, P., & Bharath Kumaran, E. (2013). Design of a digital PLL using 0.35 μ m CMOS technology. *Middle-East Journal of Scientific Research*, 18(12), 1803-1806.
- [35] Sudhakar, P., Jagadeesh, D., Wang, Y., Prasad, C.V., Devi, A.K., Balakrishnan, G., Kim B.S., & Song, J.I. (2013). Fabrication of Borassus fruit lignocellulose fiber/PP composites and comparison with jute, sisal and coir fibers. *Carbohydrate polymers*, 98(1), 1002-1010.
- [36] Kanniga, E., & Sundararajan, M. (2011). Modelling and characterization of DCO using pass transistors. In *Future Intelligent Information Systems*, 86(1), 451-457. Springer, Berlin, Heidelberg.
- [37] Sachithanandam, P., Meikandaan, T.P., & Srividya, T. Steel framed multi storey residential building analysis and design. *International Journal of Applied Engineering Research*, 9(22), 5527-5529.
- [38] Kaliyamurthi, K.P., Udayakumar, R., Parameswari, D., & Mugunthan, S.N. (2013). Highly secured online voting system over network. *Indian Journal of Science and Technology*, 6(S6), 4831-4836.
- [39] Sathyaseelan, B., Manikandan, E., Lakshmanan, V., Baskaran, I., Sivakumar, K., Lachchumananandasivam, R., Kennedy, J., & Maaza, M. (2016). Structural, optical and morphological properties of post-growth calcined TiO₂ nanopowder for opto-electronic device application: Ex-situ studies. *Journal of Alloys and Compounds*, 671, 486-492.
- [40] Saravanan, T., Sundar Raj M., & Gopalakrishnan K. (2014). SMES technology, SMES and facts system, applications, advantages and technical limitations. *Middle - East Journal of Scientific Research*, 20(11), 1353-1358.
- [41] Arputharmy, B., & Arockiam, L. (2015). Data Integration in Big Data Environment. *Bonfring International Journal of Data Mining*, 5(1), 01-05.
- [42] Meymari, B.K., Mofrad, R.F., & Nasab, M.S. (2015). High Dynamic Range Receiver System Designed for High Pulse Repetition Frequency Pulse Radar. *International Academic Journal of Innovative Research*, 2(9), 1-20.
- [43] Abinaya, R., Abinaya, R., Vidhya, S., & Vadivel, S. (2014). Latent Palm Print Matching Based on Minutiae Features for forensic Applications. *International Journal of Communication and Computer Technologies*, 2(2), 85-87.
- [44] Dr. Krishnapriya, G. (2017). Identification of Money Laundering based on Financial Action Task Force Using Transaction Flow Analysis System. *Bonfring International Journal of Industrial Engineering and Management Science*, 7(1), 01to04.
- [45] Vakilfard, M., Taheri, A., & Salehifar, M.R. (2014). Implementation of the Satellite Ground Station Control in Real-Time Under Windows. *International Academic Journal of Science and Engineering*, 1(1), 1-9.
- [46] Aarathi, S., & Vijay, N. (2014). Sophisticated Data Entry Application using Matchmaking Algorithm through Scanned Images. *International Journal of System Design and Information Processing*, 2(1), 27-29.
- [47] Patidar, H.P., & Sharma, N. (2016). Adaptive Approach of DSR and OLSR Routing Protocols Using Optimal Probabilistic Logical Key Hierarchy in MANET. *Bonfring International Journal of Networking Technologies and Applications*, 3(2), 13-20.
- [48] Venkateswara Rao, B., and Nagesh Kumar, G.V. (2014). Voltage Collapse Proximity Indicator based Placement and Sizing of Static VAR Compensator using BAT Algorithm to Improve Power System Performance. *Bonfring International Journal of Power Systems and Integrated Circuits*, 4(3), 31-38.
- [49] Neenu Preetam, I., & Gupta, H. (2014). Cardless Cash Access using Biometric ATM Security System. *International Scientific Journal on Science Engineering & Technology*, 17(10), 893-897.
- [50] Revathi, M., Prakash, K., & Suguna, R. (2018). A Systematic Study on Cyber Physical System. *Bonfring International Journal of Research in Communication Engineering*, 8(1), 1-4.