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## Contents

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Paper Title</th>
<th>Author(s)</th>
<th>Pg. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SIMULATION AND HARDWARE IMPLEMENTETATION OF GRID CONNECTED SOLAR CHARGE CONTROLLER WITH MPPT</td>
<td>Prof. Vipul Patel, Prof. Sanjay Patel</td>
<td>6-10</td>
</tr>
<tr>
<td>2.</td>
<td>DIMINISHING THE REQUIREMENT OF POWER USING PLC AND SCADA SYSTEMS IN POWER GRID SYSTEM</td>
<td>T.Vignesh, J.Kirubakaran</td>
<td>11-15</td>
</tr>
<tr>
<td>3.</td>
<td>ATTACK RESISTANT VISUALLY AUTHENTICATED AND SECURED SYSTEM</td>
<td>Snigdha Bhardwaj, R.Prathyusha, Rajeeesh Kumar</td>
<td>16-19</td>
</tr>
<tr>
<td>4.</td>
<td>SMART LOCOMOTIVE ENGINE USING GPS SYSTEM</td>
<td>N.Lakshmipriya, V.Balamurugan, K.Manikandan &amp; V.Chandra Sekar</td>
<td>20-24</td>
</tr>
<tr>
<td>5.</td>
<td>SENSORLESS CONTROL OF BLDC MOTOR DRIVE USING A HYSTERESIS COMPARATOR AND BACK EMF TECHNIQUE</td>
<td>S.Meivel1, &amp; A.Venilla &amp;A.Govindarasu</td>
<td>25-32</td>
</tr>
<tr>
<td>6.</td>
<td>TRAUMATIZED ARTICULAR CARTILAGE OF KNEE JOINT TREATED WITH BONE MARROW MESENCHYMAL STEM CELLS IN WISTAR ALBINO RATS</td>
<td>Nirmal Kumar K, Kalyanapanchakshari P</td>
<td>33-38</td>
</tr>
</tbody>
</table>
SIMULATION AND HARDWARE IMPLEMENTATION OF GRID CONNECTED SOLAR CHARGE CONTROLLER WITH MPPT

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Abstract— A renewable energy source plays an important role in electricity generation. Various renewable energy sources like wind, solar, geothermal, ocean thermal, and biomass can be used for generation of electricity and for meeting our daily energy needs. Energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness. On an average, the sunshine hour in India is about 6hrs annually also the sun shine shines in India for about 9 months in a year. Electricity from the sun can be generated through the solar photovoltaic modules (SPV). The SPV comes in various power output to meet the load requirement [1]. Maximization of power from a solar photovoltaic module (SPV) is of special interest as the efficiency of the SPV module is very low. A peak power tracker and DC-DC Boost Converter is used for extracting the maximum power from the SPV module. And simulation in PSIM software and hardware result is compared and solar panel maximum efficiencies is increase nearby 85% using dither routine algorithm method use.

Keywords— PV module, Battery, Grid, Maximum Power Point Tracking (MPPT) module, Inverter, PSIM, Boost converter.

Introduction
Renewable energy sources play an important role in electricity generation. Various renewable energy sources like wind, solar, geothermal, ocean thermal, and biomass can be used for generation of electricity and for meeting our daily energy needs. Energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness. On an average, the sunshine hour in India is about 6hrs annually also the sun shine shines in India for about 9 months in a year. A worldwide concern for future access to affordable, sustainable energy is driving the development of more efficient solar power generation [2]. In any photovoltaic (PV) based system, the master controller is a critical component responsible for the control of electricity flow between the module, battery, loads, grid. The proposed for maximum power point tracking, boost converter, battery charging, and load control. The main elements of maximum power point tracking system for dc-dc boost converter, battery charging circuit, PIC controller which selects energy sources to continue supply the load. Using the simulation software PSIM proposed boost converter topology with predictive control has been chosen.

The final simulation of dc-dc boost converter has been done, which was made in PSIM. It is shown that the output voltage (30 Vdc) to supply the load and, to charge the battery if solar output power is greater than the load power. The proposed control algorithm including the whole system control is implemented on a low cost, microcontroller PIC16F690. solar system efficiency increase near 90%.

Simulation of DC-dc boost converter in psim
The boost converter, also known as the step-up converter, is another switching converter that has the same components as the buck converter, but this converter produces an output voltage greater than the source. The ideal boost converter has the five basic components, namely a power semiconductor switch, a diode, an inductor, a capacitor and a PWM controller. The placement of the inductor, the switch and diode in the boost converter is different from that of the buck converter, which is shown in the Fig.1.

Fig.1 Basic of DC-DC Boost Converter Circuit Diagram [4]

Simulation of Open Loop Dc-Dc Boost Converter & Result
The simulation of DC-DC Boost converter is shown in the Fig.2.

Fig.2 Simulation of PV with Open Loop DC-DC Boost Converter

[1] simulation software PSIM proposed boost converter topology with predictive control has been chosen.
[2] The final simulation of dc-dc boost converter has been done, which was made in PSIM. It is shown that the output voltage (30 Vdc) to supply the load and, to charge the battery if solar output power is greater than the load power. The proposed control algorithm including the whole system control is implemented on a low cost, microcontroller PIC16F690. solar system efficiency increase near 90%.

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Fig. 3 (a), (b) and (c) shows that the output waveform of open loop DC-DC Boost converter of solar panel output power 25W, output current 0.75A and output voltage of 30V respectively.

a. Result of Open Loop DC-DC Boost Converter of Solar Panel Power 25W

(b) Result of Open Loop DC-DC Boost Converter for Output Current 0.75A, (C) Result of Open Loop DC-DC Boost Converter output voltage 30V

Fig. 4 (a) Switching Wave of MOSFET Using Open Loop DC-DC Boost Converter, (b) Voltage across Inductor Wave of Open Loop DC-DC Boost Converter

Fig. 4 (a) and (b) shows that the switching wave of MOSFET Using Open Loop DC-DC Boost Converter and Voltage across Inductor Wave of Open Loop DC-DC Boost Converter respectively [6].

Hardware circuit diagram of boost converter

A circuit diagram is required to implementation of hardware model, which is shown in the Fig. 5 [5].

Fig. 5 Circuit Diagram of Open Loop DC-DC Boost Converter
Based on the hardware circuit diagram the model could be prepared, which is shown in the Fig.6.

Fig.6 Snapshot of Open Loop DC-DC Boost Converter

Fig.7 shows that the hardware result of boost converter with MPPT.

Fig.7 3% Input duty Cycle and O/p voltage 11.5V waveform

Fig.8 32% Input duty cycle and O/P voltage 28V waveform

Fig.9 Voltage across Inductor Wave of DC-DC Boost Converter Hardware Result

Table No.1 shows that the testing result of hardware with solar panel. Which is graphically represented in the Fig.12 and Fig.13 identically.

**TABLE NO.1**

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<tr>
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<tr>
<td>1</td>
<td>0</td>
<td>21.5</td>
<td>0*21.5=0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>20</td>
<td>0.2*20=4</td>
<td>10</td>
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<tr>
<td>3</td>
<td>0.4</td>
<td>19.5</td>
<td>0.4*19.5=7.8</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>0.6</td>
<td>18.5</td>
<td>0.6*18.5=11.1</td>
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<tr>
<td>5</td>
<td>0.8</td>
<td>17.8</td>
<td>0.8*17.8=14.2</td>
<td>40</td>
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<tr>
<td>6</td>
<td>1.47</td>
<td>17.5</td>
<td>1.47*17.5=25.7</td>
<td>48</td>
</tr>
<tr>
<td>7</td>
<td>1.47</td>
<td>16</td>
<td>1.47*16=23.5</td>
<td>60</td>
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<tr>
<td>8</td>
<td>1.47</td>
<td>15</td>
<td>1.47*15=22.0</td>
<td>70</td>
</tr>
<tr>
<td>9</td>
<td>1.47</td>
<td>14.5</td>
<td>1.47*14.5=21.3</td>
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</tr>
</tbody>
</table>
The software to control the Maximum Power Point Converter can be broken into two algorithms: Current Reduction and the dither routine, which are controlled via the Interrupt Service Routine (ISR). Both algorithms manipulate the current of the solar panel via the Programmable Voltage reference generated by the PIC16F690’s 10-bit PWM.

Fig. 10 Hardware Block Diagram of MPPT

Fig. 11 48% O/P Voltage Duty Cycle and O/P Voltage 30 V Waveform

Fig. 12 (a) V-I Characteristics Solar System, (b) Duty Cycle Vs Current

Fig. 13 (a) Duty Cycle Vs O.C.Voltage, (b) Duty Cycle Vs Power

Fig. 13 shows that the final implementetation of hardware with results.
Fig.13 Snapshot of Final MPPT System Hardware

**Conclusion**

Above hardware in Dither Routine technique and PIC Controller (16F690) can be used to implement Maximum power tracking logic and as a result we can tack maximum power at output (load) from solar panel. Increase solar system efficiency is near the 90%. Shortcomings and execution efficiency for three power-feedback type MPPT methods, including perturbation & observation, incremental conductance and Dither Routine. The PV Simulation in PSIM software use.

The model of PV modules used in PV simulation system is established according to the electrical specifications of the PV module after accomplishing the model of PV modules, the models of DC-DC boost converter and MPPT systems are combined with it to complete the PV simulation system with the MPPT function. The accuracy and execution efficiency for each MPPT algorithm can then be simulated under different weather conditions after in system to use battery is charge with connected inverter to dc o/p converted into ac power. In this solar system to use and maximum efficiency increase to near 90%.Dither Routine algorithm is other algorithm to compare accurate result and high efficiency.

**Acknowledgment**

WE WOULD LIKE TO THANK TOPSUN ENERGY LTD., GANDHINAGAR, FOR GIVING US AN OPPORTUNITY TO PERFORM THE PROJECT UNDER ITS PREMISES AND GIVE ME THE INDUSTRIAL EXPOSURE WITH GREAT LEVEL OF RESEARCH PLATFORM. WE WOULD ALSO THANKFUL TO OUR COLLEAGUES AND FRIENDS FOR THEIR KIND HELP.

**References**

DIMINISHING THE REQUIREMENT OF POWER USING PLC AND SCADA SYSTEMS IN POWER GRID SYSTEM

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ABSTRACT
Power management is an important constraint in the design of various loads in industries for automation. So if power consumption increases then the substation monitoring is very important for the purpose of controlling the hardware and software optimization with the help of PLC ladder logic system and SCADA were used. This technique in order to reach strong conclusion about their actual impact on the power grid monitoring and control without manpower. The basic idea behind substation control project is to monitor the switchyards in substation. In substation many relays and circuit breakers are used. When any one breaker is trip because of the problems, we can monitor and control through SCADA windows. In power management project, the computer is used for assigning the priority for various loads. The signals are given to the computer of the electricity board where there is the electronic control unit which controls the sequence of disconnecting the load. On basis of controls from the computer the breakers are managed and in computer the SCADA system is installed which is used for monitoring and control. If there any problem occurs in plant, we can easily identify which part is trip. After that we can troubleshoot the problem through manpower and monitor the substation.

KEYWORDS: PLC, SCADA, Power grid system, Fault isolation.

INTRODUCTION
SCADA
The combination of telemetry and data acquisition is referred as SCADA (Supervisory Control And Data Acquisition system). The SCADA encompasses the collecting of information via RTU (Remote Terminal Unit) relocating it back to central site carrying out decisive rehash and control and then displaying that information on a number of operating screens or displays. SCADA systems are highly distributed systems used to control geographically dispersed assets, often scattered over thousands of square kilometers, where centralized data acquisition and control are critical to system operation. They are used in distribution systems such as water distribution and wastewater collection systems, oil and gas pipelines, electrical power grids, and railway transportation systems.

A SCADA control center performs centralized monitoring and control for field sites over long-distance communications networks, including monitoring alarms and processing status data. Based on information received from remote stations, automated or operator-driven supervisory commands can be pushed to remote station control devices, which are often referred to as field devices. Field devices control local operations such as opening and closing valves and breakers, collecting data from sensor systems, and monitoring the local environment for alarm conditions. A SCADA system gathers data from sensors and instruments located to remote sides. Then, it transmits data at a central site for controller monitoring process. Automation systems are used to increase the efficiency of process control by trading off high personnel costs for low computer system costs. These automation systems are often referred to as process control system (PCS) or supervisory control and data acquisition (SCADA) systems, and the widespread use of such systems makes them critical to the safe, reliable, and efficient operation of many physical processes.

BLOCK DIAGRAM OF SCADA

The broad architecture of a SCADA involves physical equipment such as switches, pumps, and other devices able to be controlled by a Remote Telemetry Unit (RTU). The dual roles of the master computers are to provide the information such as meter readings...
and equipment status to human operators in a digestible form and to allow the operators to control the field equipment the master computers, and interface with the system using operator consoles which communicate with the master computers over a network.

Master Terminal Unit (MTU) – allows operators to view the state of any part of the plant equipment and drives most operator interaction with the by alarms. It provides displays of process status information, including alarms and other means.

Interfacing – allows communications equipment from different manufacturers to be connected together. The RS 232 or RS-485 interface is designed for the connection of two devices. Two devices called: DTE (Data Terminal Equipment) communicates with a DCE device and transmits data and receives data and DCE (Data communications Equipment) transmits data between the DTE and a physical data communications link.

Remote Terminal Unit (RTU) – means a microprocessor to connect data input streams to data output streams. RTU may include a battery or charger circuitry. It is accomplished by using an isolated voltage or current source. In SCADA system, RTU is a device that collects data, codes the data into a format that is from the master device and implements processes that are directly by the master. RTUs are equipped with input channels for sensing or metering, output channels for control.

Intelligent Electronic Devices (IEDs) includes electronic meters, relays and controls on specific substation equipment. It has the capabilities to support serial communications to a SCADA sever and reports to modern RTU via communication channels. It performs all functions of protection, control, monitoring, metering and communication.

Here we use the SCADA systems for monitoring and controlling the power. Traditionally, SCADA systems have made use of the Public Switched Network (PSN) for monitoring purposes.

PLC

Programmable Logic Controller or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines. PLCs are designed for multiple analogue and digital inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. The functionality of the PLC has evolved over the years to include sequential relay control, motion control, process control, distributed control systems and networking. The data handling, storage, processing power and communication capabilities of some modern PLCs are approximately equivalent to desktop computers.

The main difference from other computers is that PLCs are armored for severe conditions (such as dust, moisture, heat, cold) and have the facility for extensive input/output (I/O) arrangements.

** BASIC BLOCK DIAGRAM OF PLC **

The above figure shows basic block diagram of PLC (Programmable Logic Controller). The CPU of PLC is programmed using a programming terminal usually through personal computers or dedicated HMIs. Basic Modules associated with the CPU are external modules and I/O modules along with bit, byte, word and double word addressable memory locations. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a bounded time.

**RELATED WORK**

Today the rapid growth of Information Technology (IT) tools has promoted many PDC to bring up to date their fault diagnosis as well as troubleshooting systems. Among new technologies used for this purpose, SCADA systems are considered as the widely appropriate tool used for such processes. Moreover, they proved the importance on using computer based system for sustainable development in the automation of the power distribution network to improve the customers’ service and the reliability of the network. Also the paper outlines the general concepts and required equipments for the automation of such power networks [1].

SCADA system can be accomplished by using PLC ladder diagram. This automated distribution system is analyzed to develop a secure, reliable and convenient management tool which can use remote terminal units (RTUs). SCADA provides management with real-time data on production operations; implements more efficient control paradigms, improve plant and personnel safety, and reduces costs of operation. The security of SCADA systems depends on the effective application of security principles and
technology to the SCADA system. This paper has proposed a model that illuminates the categories of data, functionality, and interdependencies present in a SCADA system. [2]. Main concept of the paper is data acquisition & controlling by using SCADA software PLC. Here PLC is a medium between electrical system & Personal Computer for SCADA to take input and output bits. By using the parameters, we can easily control any load in our system to improve system operation, system reliability, etc. Alternatively, SCADA and PLC communication system make it possible to integrate protection control and monitoring electrical parameter together for maximum benefit. [3].

Open loop distribution system is the distribution configuration system used as TNB distribution system. It is the first DAS research work done on customer side substation for operating and controlling between the consumer side system and the substation. This research helps to optimize staff efficiency by deploying staff to on-site location only when necessary. It is the first DAS research work done on customer side substation for operating and controlling between the consumer side system and the substation. The operating system described here can reduce the number of customers that experience outages [4]. The system provides opportunity for managing faults by creating faults database and assessing the performance index. The approach offers enhanced performance over the traditional approach and provides useful suggestion to improve delivery of power to consumers. This makes it difficult to keep track of the system reliability over a period. The developed framework which is based on the developed template accepts the report from the fault log or from the message log data. The approach offers enhanced performance over the traditional approach and provides useful suggestion for improved delivery of power to consumers [5].

This novel automated fault isolation system has been developed and integrated into a new customer side distribution system. The main contribution of the work in this research project is to develop and design a distribution automation system aimed at the low voltage (LV) distribution system [6] In this paper they used different methods for generation of electricity like wind, PV (photovoltaic), hydro, biogas & distributed using PLC & controlling using SCADA. Due to Energy Management System using PLC & SCADA operational cost decreases & also easy to handle. Online monitoring & distribution of energy is possible due to this developed Energy Management System [7].

POWER GRID SYSTEM

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers. Power stations may be located near a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often located away from heavily populated areas. They are usually quite large to take advantage of the economies of scale. The electric power which is generated is stepped up to a higher voltage at which it connects to the transmission network.

A substation receives its power from the transmission network; the power is stepped down with a transformer and sent to a bus from which feeders fan out in all directions across the countryside. These feeders carry three-phase power, and tend to follow the major streets near the substation. As the distance from the substation grows, the fan-out continues as smaller laterals spread out to cover areas missed by the feeders. This tree-like structure grows outward from the substation, but for reliability reasons, usually contains at least one unused backup connection to a nearby substation. This connection can be enabled in case of an emergency, so that a portion of a substation's service territory can be alternatively fed by another substation. All power systems have three major components: Generation, Load and Transmission.

- Generation: Creates electric power.
- Load: Consumes electric power.
- Transmission: Transmits electric power from generation to load.

Electricity is expected to see growing demand in the future. The Information Revolution is highly reliant on electric power. Other growth areas include emerging new electricity-exclusive technologies, developments in space conditioning. Benefits of Implementing SCADA systems for Electrical Distribution are

- Increases reliability through automation.
- Eliminates the need for manual data collection.
- Alarms and system-wide monitoring enable operators to quickly spot and address problems.
- Automation protects workers by enabling problem areas to be detected and addressed automatically.
- Operators can use powerful trending capabilities to detect future problems, provide better routine maintenance of equipment and spot areas for improvement.
- Historians provide the ability to view data in various ways to improve efficiency.
In SCADA monitoring, five windows are used. In control window, we can control the switching process and monitor the voltage and current parameter of the transformer.

**BLOCK DIAGRAM**

In substation window, the connection of switches and circuit breakers are monitoring the operating status. In Indication window, the Circuit Breakers are monitor separately. Is there any Circuit Breaker is trip, the corresponding switch is indicate through lamp. By using this indication window, we can identify the fault location. In Trend window, the graph is shown for monitor the voltage and current values of transformers. In Alarm window, the low and high rating current and voltage is update each changes in substation. The alarm is indicate like ‘LOW’ & ‘HIGH’ of corresponding tag names used in SCADA. If we want to shutdown the system, we can give command through SCADA. This SCADA is interface with the PLC for control operation. The Hard ware switches are connected to PLC inputs based on their addressing.

**SIMULATION TOOL**

- Creating new application
- Creating windows
- Tag definition
- Drawing objects
- Animation properties
- Writing scripts
- Real time trends
- Historical trends
- Alarms

**PROPOSED SYSTEM**

SCADA role in Substation: Total plant is monitoring their operation in control room itself. High/Low Alarm is update frequently with respect to the measuring equipments. The graphs are run in the trend window. In this trend we can get the old data for yearly auditing purpose. In any emergency condition, we can shut down the total system. By using this SCADA, we can reduce the man power and time delay of operation.

**CONTROL WINDOW**

Substation automation refers to using data from Intelligent (IED), control and automation capabilities within the substation, and control commands from remote users to control power-system devices. Since full substation automation relies on substation integration, the terms are often used interchangeably. Power-system automation includes processes associated with generation and delivery of power. Monitoring and control of power delivery systems in the substation and on the pole to reduce the occurrence of outages and shorten the duration of outages that do occur. The IEDs, communications protocols, and communications methods, work together as a system to perform power-system automation.

**SUBSTATION WINDOW**

TREND meter is based on standard measurements and data export methods. The TREND meter provides you with easy to read, graphed energy consumption and load information of each measured device. The TREND meter represents the starting point towards a more complex tool able to monitor a network infrastructure and to trigger energy saving techniques when traffic conditions change. Our tool has been developed inside the context of the European project TREND (Towards Real Energy Efficient Network design), which actually supported this work. The main goal of the TREND meter is to collect measurements of power and utilization from a variety
of devices located in the Internet. The idea is to build a centralized server which collects the measurements from the devices. As second goal, the TREND meter aims at consolidating these measurements together to study whether there are similarities or not in the patterns of power and utilization of the devices. Additionally, the TREND meter aims at making publicly available the collected data to the community, and to easily show this information with a graphical representation. The design of TREND meter architecture had to face a complex and very heterogeneous scenario.

ADVANTAGE OF PROPOSED METHOD
- Reduced manpower.
- Time delay is reduced.
- In control room itself monitor the plant and give commands through user.
- Economical and safe operation
- Is there any modification and future extension, we can easily update in PLC & SCADA.
- In substation, many switches are used, if there any one of the switch is trip means we can easily identify the particular area.

CONCLUSION
SCADA provides management with real-time data on production operations, an implement more efficient control paradigms, improves plant and personnel safety, and reduces costs of operation. The proposed model that illuminates the categories of data, functionality, and interdependencies present in a SCADA. The model serves as a foundation for further research on how to best apply technical controls in substation and domestic distribution areas.

REFERENCES
ATTACK RESISTANT VISUALLY AUTHENTICATED AND SECURED SYSTEM

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ABSTRACT:
Keylogging or keyboard capturing is the activity of recording (or logging) the keys struck on a keyboard, normally in a secretive way so that the individual utilizing the keyboard is unconscious that their activities are being observed. It likewise has exceptionally authentic uses in investigations of human-computer interaction. There are various keylogging techniques, extending from hardware and software based methodologies to acoustic examination. Including human in authentication protocols, while guaranteeing, is not simple in light of their restricted capacity of calculation and remembrance. We exhibit how careful visualization outline can improve the security as well as the convenience of authentication. We propose two visual authentication protocols: one is a one-time-password protocol, and the other is a password-based authentication protocol. Our approach for genuine arrangement: we had the capacity attain to an abnormal state of ease of use while fulfilling stringent security necessities.

Keywords: keylogging, authentication protocols, acoustic analysis, visual authentication, security.

1. INTRODUCTION
Keylogging exhibits an extraordinary test to security supervisors. Dissimilar to customary worms and viruses, certain sorts of keyloggers are everything except difficult to discover. Keyloggers are a kind of malware that malignantly track customer information from the comfort attempting to recuperate individual and private information. Growing machine use for essential business and individual activities using the Internet has made feasible treatment of keylogging basic. Cybercriminals have fictional various schedules to get sensitive information from your endpoint devices. On the other hand, few of them are as effective as keystroke logging. Keystroke logging, generally called keylogging, is the hold of imprint characters. The data caught can incorporate report content, passwords, user ID's, and other potentially touchy bits of information. Using this approach, an assailant can get essential data without breaking into a cemented database or file server.

A keylogger is modifying, proposed to capture the larger part of a customer's support strokes, and a while later make use of them to copy a customer in money related trades. Case in point, at whatever focuses a customer sorts in her watchword in a bank's sign in box, the keylogger gets the mystery word. The risk of such keyloggers is pervasive and can be display both in PCs and open corners; there are constantly circumstances where it is imperative to perform monetary trades using an open machine regardless of the way that the best concern is that a customer's watchword is prone to be stolen in these machines. Far and away more terrible, keyloggers, frequently root kitted, are tricky to identify since they won't appear in the assignment director methodology list. To relieve the keylogger attack, virtual or onscreen consoles with random console game plans are generally utilized as a part of practice. Both procedures, by revising letter sets randomly on the catches, can baffie basic keyloggers. Lamentably, the keylogger, which has control over the entire PC, can without much of a stretch capture each occasion and read the video buffer to make a mapping between the clicks and the new letter set. An alternate moderation procedure is to utilize the console snaring counteractive action strategy by bothering the console interferes with vector table [1].

On the other hand, this strategy is not general and can interfere with the working framework and local drivers. It is insufficient to depend just on cryptographic strategies to counteract attacks which mean to swindle clients' visual experience while living in a PC. Regardless of the fact that all vital data is safely conveyed to a client's machine, the attacker living on that client's machine can without much of a stretch watch and change the data and show legitimate looking yet misleading data. Human client's contribution in the security convention is off and on again important to keep this sort of attacks however people are bad at muddled estimations and don't have a sufficient memory to recall cryptographically solid keys and marks. Accordingly, ease of use is a critical variable in outlining a human-including convention [2].

Our methodology to taking care of the issue is to present a transitional gadget that extensions a human client and a terminal. At that point, rather than the client straightforwardly conjuring the general confirmation convention, she conjures a more complex yet easy to use convention by means of the moderate helping gadget. Each association between the client and a middle of the road helping gadget is envisioned utilizing a Quick Response (QR) code. The objective is to keep client encounter the same as in legacy confirmation routines however much as could be expected, while forestalling keylogging attacks. Consequently, in our conventions, a client does not have to retain additional data aside from a customary security token, for example, secret key or PIN, and dissimilar to the former writing that safeguards against ought to surfing attacks by obliging complex reckonings and far reaching inputs. All the more particularly, our methodology envisions the security procedure of validation utilizing an advanced mobile phone helped increased reality.

In this paper, we show how visualization can improve security as well as convenience by proposing two visual verification conventions: one for password-based authentication, and the other for one-time-password. Through thorough investigation, we demonstrate that our conventions are safe to a number of the testing attacks relevant to different conventions in the writing. Besides, utilizing a broad research endeavor on a model of our conventions, we highlight the capability of our conventions in genuine arrangement tending to client's inadequacies and constraints. The main contributions of this paper are as follows:
1. Two protocols for authentication that use visualization by method for increased reality to give both high security and high convenience. We demonstrate that these conventions are secure under a few certifiable attacks including keyloggers. Both conventions offer favorable circumstances because of visualization both as far as security and ease of use.

2. Model usage as Android applications which show the ease of use of our conventions in true organization settings.

The rest of this paper is organized as follows. In section II, related work; section III contains proposed methodology; Enhancement in section IV; experimental results in section V; finally conclusion in section VI.

II. RELATED WORK

There has been an extensive assemblage of deal with the issue of client authentication and in the connection of e-banking money. Of uncommon investment are authentication protocols that utilization graphical passwords. To the best of our insight, our protocols are the first of their sort to utilize visualization for enhancing security and ease of use of authentication protocols according to the path reported in this paper. A closely related vein of research is trust establishment for group communication using cognitive capabilities. Examples of such works include SPATE [3], GA nGS [4], and Safe Slinger [5]. None of these works use visualization as reported in this work, although they provide primitives for authentication users and establishing trust. Another closely related work is “Seeing-is-Believing” (SiB) [6] (extended in [7]), which uses visual channels of 2D barcodes to resist the man-in-the-middle attack in device pairing. Though we utilize similar tools by using the 2D barcodes for information representation, and the visual channel for communicating this information, our protocols are further more generic than those proposed in [6]. Our protocols are tailored to the problem settings in hand, e-banking, with a different trust and attack model than that used in [6]—which results into different guarantees as explained earlier in this paper. To prevent against phishing, Parno et al. suggested the use of trusted devices to perform mutual authentication and eliminate reliance on perfect user behavior [8]. Slightly touched upon in this paper are keyloggers as potential attacks for credentials stealing, which are reported in [9], and other malwares which are reported in [10]. In this paper we have shown that our protocols are secure even when one of the participants in the authentication process (the terminal or smartphone) is compromised.

III. KEYLOGGING-RESISTANT VISUAL AUTHENTICATION PROTOCOLS

In this section, we describe two protocols for user authentication with visualization. Before getting into the details of these protocols, we review the notations for algorithms used in our protocols as building blocks. Our system utilizes the following algorithms:

- **Enck (·)**: an encryption algorithm which takes a key k and a message M from set M and outputs a cipher-text C in the set C.
- **Decr (·)**: a decryption algorithm which takes a ciphertext C in C and a key k, and outputs a plain-text (or message) M in the set M.
- **Sign (·)**: a signature generation algorithm which takes a private key SK and a message M from the set M, and outputs a signature σ.
- **Verf (·)**: a signature verification algorithm which takes a public key PK and a signed message (M, σ), and returns valid or invalid.
- **QREnc (·)**: a QR encoding algorithm which takes a string S in S and outputs a QR code.
- **QRDec (·)**: a QR decoding algorithm which takes a QR code and returns a string S in S.

Any public key encryption scheme with IND-CCA2 (Indistinguishability against Adaptive Chosen Cipher-text Attacker) security would be good for our application. A public key encryption scheme with IND-CCA2 adds random padding to a plain-text, which makes the cipher-text different whenever encrypted. This restriction on the type of the used public key encryption scheme will prevent an attacker from checking whether his guess for the random layout is right or not. Thus, the security of the scheme is not dependent on the number of possible layouts but the used encryption scheme. If no such encryption is used, the 1-1 mapping of plaintext to cipher text does not hold anymore and launching the attack will not be possible at the first place. Also, any signature scheme with EUF-CMA (existential-unforgeability against adaptive chosen-message attacker) can be used to serve the purpose of our system.

A. Authentication With Random Strings:

In this section, we introduce an authentication protocol with a one-time-password (OTP). The following protocol relies on a strong assumption; it makes use of a random string for authentication. The protocol works as follows:

1. The user connects to the server and sends her ID.
2. The server checks the ID to retrieve the user’s public key (PKID) from the database. The server then picks a fresh random string OT P and encrypts it with the public key to obtain EOT P = EncPKID (OT P).
3. In the terminal, a QR code QREOT P is displayed prompting the user to type in the string. 4) The user decodes the QR code with EOT P = QRDec (QREOT P). Because the random string is encrypted with user’s public key (PKID), the user can read the OTP string only through her smartphone by OT P = Decr (EOT P) and type in the OT P in the terminal with a physical keyboard.
5. The server checks the result and if it matches what the server has sent earlier, the user is authenticated. Otherwise, the user is denied. In this protocol, OT P is any combination of alphabets or numbers whose length is 4 or more depending on the security level required.

B. An Authentication Protocol with Password and Randomized Onscreen Keyboard

Our second protocol, which is referred to as Protocol 2 in the rest of this paper, uses a password shared between the server and the user, and a randomized keyboard. The protocol works as follows:

1. The user connects to the server and sends her ID.
2) The server checks the received ID to retrieve the user’s public key (PKID) from the database. The server prepares π, a random permutation of a keyboard arrangement, and encrypts it with the public key to obtain $E_{KID}(\pi)$. Then, it encodes the cipher-text with QR encoder to obtain $Q_R\text{Enc}(E_{KID}(\pi))$. The server sends the result with a blank keyboard.

3) In the user’s terminal, a QR code ($Q_R\text{Enc}(E_{KID}(\pi))$) is displayed together with a blank keyboard. Because the onscreen keyboard does not have any alphabet on it, the user cannot input her password. Now, the user executes her smartphone application which first decodes the QR code by applying $Q_R\text{Dec}(Q_R\text{Enc}(E_{KID}(\pi)))$ to get the ciphertext ($E_{KBD}$). The ciphertext is then decrypted by the smartphone application with the private key of the user to display the result ($\pi = \text{DecrSKID}(E_{KBD})$) on the smartphone’s screen.

4) When the user sees the blank keyboard with the QR code through an application on the smartphone that has a private key, alphanumerics appear on the blank keyboard and the user can click the proper button for the password. The user types in her password on the terminal’s screen while seeing the keyboard layout through the smartphone. The terminal does not know what the password is but only knows which buttons are clicked. Identities of the buttons clicked by the user are sent to the server by the terminal.

5) The server checks whether the password is correct or not by confirming if the correct buttons have been clicked.

Some of the technical issues in the two protocols that we have introduced in the previous sections call for further discussion and clarification. In this section, we elaborate on how to handle several issues related to our protocols, such as session hijacking, transaction verification, and securing transactions.

IV. ENHANCEMENT

1. In this paper we developed enhancement is offline transaction. Mostly transactions are done through online only. But for time consuming and quick transaction we proposed offline transaction. In offline transaction user generate one file, inside that file user acc-no, transaction amount, and etc are available. Those details are prepared by user when they are in offline. When user entered into online, they just load this file into the applications for fund transaction. Using this offline transaction, user timings are more consumed.

2. Another enhancement is IMI security. Main purpose of this is, to avoid malicious transaction. When other user knows my username and password means, they can use my details for fund transfer without my knowledge. To avoid this we are providing IMI security. Every user registration server stores their IMI number into their database. Another malicious user, use my username and password in their mobiles means IMI no vary so proper transaction will not occur.

In Protocol 1, OTP tokens that have high entropy and are human-unfriendly making them hard to remember and recall are one-time used. Accordingly, a shoulder surfer would not benefit from launching an attack by trying to observe what the user at the terminal is inputting. The attack is not applicable to this protocol.

In Protocol 2, observing the terminal or the smartphone keyboard layout (on the smartphone screen) alone would not reveal the credentials of the user. Observing both at the same time in a shoulder surfing attack, and mapping stroked keys on the terminal to those on the smartphone screen would reveal the credentials of the user. Being able to successfully launch this attack is a non-trivial task, and requires the attacker to be in very near proximity to the user, which would raise the user’s suspicions about the intentions of the attacker. However, because the attacker who successfully conducts all this necessary steps will get a password in Protocol 2, the protocol cannot be said to be secure against the shoulder-surfing attack. We leave it for the future work to make Protocol 2 secure against the shoulder-surfing attack by combining it with shoulder-surfing resistant schemes already explored in the literature [50].

EXPERIMENTAL RESULTS

(a) QR Code Scanning (before)

(b) QR Code Scanning (after)
VI CONCLUSION

In this paper, we proposed and analyzed the use of user-driven visualization to improve security and user-friendliness of authentication protocols. Moreover, we have shown two realizations of protocols that not only improve the user experience but also resist challenging attacks, such as the keylogger and malware attacks. Our protocols utilize simple technologies available in most out-of-the-box smartphone devices. We developed Android application of a prototype of our protocol and demonstrate its feasibility and potential in real-world deployment and operational settings for user authentication. Our work indeed opens the door for several other directions that we would like to investigate as a future work. First of all, our plan is to implement our protocol on the smart glasses such as the Google glass, and conduct the user study. Second, we plan to investigate the design of other protocols with more stringent performance requirements using the same tools provided in this work. In addition, we will study methods for improving the security and user experience by means of visualization in other contexts, but not limited to authentication such as visual decryption and visual signature verification. Finally, reporting on user studies that will benefit from a wide deployment and acceptance of our protocols would be a parallel future work to consider as well.

REFERENCES:
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SMART LOCOMOTIVE ENGINE USING GPS SYSTEM
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Abstract—Rail tracking system (RTS) is an advanced method used to track and monitor any train equipped with a sensing unit that receives and transfers signals through GPS satellite. RTS is a combination of Global Positioning System (GPS) that provides actual geographic real time position of each train. The entire transmission mechanism of RTS setup depends on GPS satellite, a receiver on the train, a GSM system and controller based tracking for dispatch. The GSM communication system is generally the same as cellular phone network. In the existing system passenger cannot able to identify the train location. In this project we are identifying the train speed, location and providing message via SMS by applying GPS technique. It is very useful to the passenger those who are sleeping while travelling. In case of emergency when passenger using emergency chain, we can also indicate that in which compartment the chain is pulled.

1. Introduction

This project is aimed to track the vehicles that which mean to locate the position of the train. It is not possible in the existing train. The location of the train is indicated using GPS (global positioning system) technology. Communication link is made possible through a GPS receiver. GPS will give the information of parameters like longitude, latitude and altitude via SMS. Our project also provides a voice message in each and every compartment priorly when the nearest station is arrival. In case of emergency chain pulling indication also provided with the help of fixing the LCD display in the locomotive engine.

The various components in the block diagram are mentioned below:
1. AT89S52 Microcontroller
2. Power Supply
3. Crystal Oscillator
4. Reset
5. 16x2 Liquid Crystal Display (LCD)
6. MAX 232
7. GSM Modem
8. GPS Module

Here the communication takes place between GPS receiver and GPS satellite. GPS satellite continuously tracks the missing train and the position of the train is send to the controller from GPS receiver. train is associated with LCD display which sends the continuous information about the position of the train to the control unit and the train position should be send to the GSM.

The rest of the paper is as follow. In Section 2, we explain the proposed setup of the system i.e., the block diagram and its description. Section 3 explains the working of the proposed system. We conclude the paper in Section 4 describing our accomplishments.

2. Proposed Method

The block diagram consists of different components interfacing to a microcontroller. The block diagram is shown in Fig.1.

Fig.1: Block Diagram

2.1 Microcontroller Unit

The AT89S52 is a low-power, high performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel’s high-density nonvolatile memory technology and is compatible with the industry standard 80C51 and 80C52 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash

On a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. Features of the microcontroller:
1. It is a 8-bit microcontroller.
2. 8K Bytes of In-System Programmable (ISP) Flash Memory.
   a. -Endurance: 1000 Write/Erase Cycles
   b. Fully Static Operation: 0 Hz to 33 MHz
   c. 256 x 8-bit Internal RAM.
   d. 32 Programmable I/O Lines.
   e. Three 16-bit Timer/Counters.
   f. Eight Interrupt Sources.
8. Full Duplex UART Serial Channel.

2.2 Power Supply
The input to the circuit is applied from the regulated power supply. The microcontroller voltage is of 5V. The A.C. input i.e., 230V from the mains supply is step down by the transformer to 12V and is fed to a rectifier. The output obtained from the rectifier is a pulsating D.C. voltage. So 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this JHD 16x2A LCD each character is displayed in 5x7 pixel matrix. The schematic diagram of 16x2 LCD is shown in Fig.2. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Some of the LCD command codes are listed in Table 1.

Features:

<table>
<thead>
<tr>
<th>Code(Hex)</th>
<th>Command to LCD Instruction Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>01 Clear display of the screen</td>
</tr>
<tr>
<td>06</td>
<td>06 Automatic increment</td>
</tr>
<tr>
<td>38</td>
<td>38 2 line 5x7 Matrix</td>
</tr>
<tr>
<td>0F</td>
<td>0F Display is on and the cursor blinks in order to get a pure D.C voltage, the output voltage from the rectifier is fed to a filter to remove any A.C components present even after rectification. Now, this voltage is given to a voltage regulator to obtain a pure constant dc voltage. We are using an IC 7805 as voltage regulator to get a 5V output voltage.</td>
</tr>
<tr>
<td>80</td>
<td>80 Force Cursor to begin from 1 and</td>
</tr>
<tr>
<td>C0</td>
<td>C0 Force Cursor to begin from 2</td>
</tr>
</tbody>
</table>

Table 1: LCD Command Codes

2.3 Crystal Oscillator
A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time (as in quartz wrist watches), to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator used is the quartz crystal, so oscillator circuits designed around them became known as “crystal oscillators”. This block provides necessary frequency sine wave to the microcontroller. This frequency is converted to square wave within the microcontroller.

2.6 Reset

Control reset is to execute the entire program cycle from beginning.

2.7 Liquid Crystal Display (LCD)
LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A

1. Interface with either 4-bit or 8-bit microprocessor.
2. Display data RAM.
3. 80x8 bits (80 characters).
4. Character generator ROM and RAM.
5. 160 different 5x7 dot-matrix character patterns.

The LCD display is connected to the output port of microcontroller to display the cyclic operations of vigilance control device.

2.12 MAX232
The microcontroller can communicate with the serial devices using its single serial port. The logic levels at which this serial port operates is TTL logics. But some of the serial devices operate at RS 232 logic levels. So in order to communicate the microcontroller with modem, a mismatch between the logic levels occurs. In order to avoid this mismatch, in other words to match the Logic levels, a serial driver is used. A MAX232 is a serial line driver used to establish communication between modem and microcontroller. The interfacing of GSM modem with microcontroller using MAX 232 as a serial line driver is shown in Fig.3. The voltage levels of Max 232 are given in Table 2.

6. 8 different users programmed 5x7 dot-matrix patterns.
7. Numerous instructions.
9. ON/OFF, Blink Character, Cursor Shift, Display Shift.

10. Built-in reset circuit is triggered at power ON.

<table>
<thead>
<tr>
<th>RS232 Line Type &amp; Logic Level</th>
<th>RS232 Voltage</th>
<th>TTL Voltage to/from MAX232</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Transmission (Rx/Tx) Logic 0</td>
<td>+3 V to +15 V</td>
<td>0V</td>
</tr>
<tr>
<td>Data Transmission (Rx/Tx) Logic 1</td>
<td>-3 V to -15 V</td>
<td>5V</td>
</tr>
<tr>
<td>Control Signals (RTS/CTS/DTR/DSR) Logic 0</td>
<td>-3 V to -15 V</td>
<td>5V</td>
</tr>
</tbody>
</table>
Table 2: Voltage levels of Max 232
The modem is provided with network status indication LED lamp. It is also provided with buzzer to indicate incoming call. The GSM modem is shown in Fig.4.

4: GSM Modem Prototype

2.13 Global System for Mobile communication (GSM)
A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. It operates at either the 900MHz or 1800MHz frequency band. It supports voice calls and data transfer speeds of up to 9.6kbits/s, together with the transmission of SMS (Short Message Service). The GSM Modem comes with a serial interface which the modem can be controlled using AT command interface. The interfacing of GSM modem with the microcontroller is shown in Fig.3.

Fig.3: Interfacing of GSM modem with microcontroller

7.3 Here a GSM modem SIMCOM made SIM300 V interfaced with the microcontroller operates in 900MHz frequency and is operated at voltage levels of 3.5 to 5V. The working of GSM modem is based on commands, the commands always start with AT (which means ATention) and finish with a <CR> character. AT commands are used to control the MODEMs. Since one of the main objective for this application is to show how to send the message, only a subset of the AT command set needs to be implemented. The AT commands are given to the GSM modem.

2.14 Global Positioning System (GPS)
The Global Positioning System (GPS) is a satellite based PC or controller and the navigation system that sends and receives radio signals. A GPS receiver acquires these signals and provides the user with information. Using GPS technology one can determine location, velocity and time, 24 hours a day, in any weather conditions anywhere in the world for free. GPS was formally known as the NAVSTAR (Navigation Satellite Timing and Ranging). The basis of the GPS technology is a set of 24 satellites that are continuously orbiting the earth. These satellites are equipped with atomic clocks and sent out radio signals as to the exact time and location. These radio signals from the satellites are picked up by the GPS receiver. Once the GPS receiver locks on to four or more of these satellites, it can triangulate its location from the known positions of the satellites. It is a higher performance, low power satellite based model. It is a cost effective and portable system which accurately detects the location. The GPS receiver used here is Sky Traq Venus 6 GPS module ST22 which is having TTL logics and also RS232 as option. The GPS receiver is shown in Fig.5. This GPS is used to track the position of the train after the emergency brake is applied in order to avoid the accidents. This application is used only after the train is
stopped
SMART LOCOMOTIVE ENGINE USING GPS SYSTEM

The flow chart shown in Fig.6 gives the clear explanation of the working of the modern vigilance control device. By using this flow chart the source code is developed. The source code is written in embedded C language. The map according to the co-ordinates is as follows.

Fig.5: GPS Receiver
GPS Receiver
Specifications:
1. 65 channels-1Hz Update rate
2. Hot Start- 1sec
3. Baud rate- 9600bits/s
4. Operating Voltage-5Volts dc
5. O/P Format-NMEA 0183-RS232
6. Operating Temperature: -40 to +85 C
7. Sensitivity- Tracking: -160 dBm

Reacquisition: -158 dBm
Cold Start (Autonomous): -148 dBm

3. Working

Soon after applying the power supply, the naming of the project will be displayed and it waits for the input message which can be sent from our mobile. An additional of an individual speaker are located to the train compartment and it will indicate where the train is reached by an audio message if a passenger in needs to find his train where it is located, so that passenger can type the train name and train number and sends the message to a particular number, the GPS located in the train receives the users request and the position can be transferred by GPS and speed of train can be calculated by speed sensor. the capture datas can be converted into ASCII format and the message is again to the passenger. in case of emergency when passenger using emergency chain we can also indicate that in which compartment the chain is pulled. in the LCD display which located in locomotive engine.

Fig. 6: Flow chart of the System

4. Conclusion

This method of tracking a vehicle is enormous and very applicable. It is even advantageous for rail tracking to know the accurate position of the train. We can upgrade it for touch screen system which is already running in the railways. We can implement very widely so that every passenger can know about the train status being anywhere and
he/she can be in time there.

5. Result

REFERENCES
Sensorless Control of BLDC Motor Drive Using a Hysteresis Comparator and back emf technique

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Abstract- This paper describes the brushless dc (BLDC) motor sensorless control system for hydraulic oil pump. The sensorless techniques that are based on a hysteresis comparator the basic implementation of hysteresis current control is based on deriving the switching signals from the comparison of the current and voltage method with a high starting torque are suggested. The hysteresis comparator is used to compensate for the phase delay of the back EMFs. The concept of the application is that of a drive using Back-EMF Zero Crossing technique for position detection. It prevent multiple output transitions from noise or ripple in the terminal voltages. The rotor position is aligned at standstill for maximum starting torque. Also, the stator current can be easily adjusted by modulating the pulse width of the switching devices during alignment. Some experiments are implemented on a single chip PIC controller to demonstrate the feasibility of the suggested sensorless and start-up techniques. Index Terms-Brushless dc (BLDC) motor, hysteresis comparator, sensorless control, start-up technique.

I. INTRODUCTION

In recent years, the brushless dc (BLDC) motor is receiving much interest in automotive applications especially on hydraulic oil pump due to its high efficiency, compact size, and lower maintenance when compared to a brush dc motor. In order to obtain an accurate and ripple-free instantaneous torque of the BLDC motor, the rotor position information for stator current commutation must be known, which can be obtained using hall or position sensors mounted on a rotor. This results in a high costs as well as poor reliability, which are serious problems at the vehicle applications. To cope with the aforementioned restriction, many position sensorless algorithms have been considered as potential solutions. Three phase Brushless DC (BLDC) motors are good candidates because of their high efficiency capability and easy to drive features. The disadvantage of this kind of motor is the fact that commutation of motor phases relies on its rotor position. Although the rotor position is usually sensed by sensors, there are applications that require sensorless control. Benefits of the sensorless solution are elimination of the position sensor and its connections between the control unit and the motor.

The sensor less rotor position technique detects the zero crossing points of Back-EMF induced in the motor windings. The phase Back-EMF Zero Crossing points are sensed while one of the three phase windings is not powered. The obtained information is processed in order to commutate energized phase pair and control the phase voltage, using Pulse Width Modulation. The zero-crossing of the back EMF measured from the stator winding is detected and the commutation points can be estimated by shifting 30 from the zero crossing of the back EMFs. The performance of the sensorless drive Deteriorates with the phase shifter in the transient state. Also, it is sensitive to the phase delay especially at the high speed. Several phase shifters to compensate for phase error induced of back EMFs are proposed. They require an additional compensation circuit including the timers. The position information is extracted by integrating the back EMF of the silent phase. This method has an error accumulation problem at low speed. The sensorless control techniques using the phase-locked loop (PLL) and the third-harmonic back EMF are suggested. Furthermore, the drift angle varies as the motor parameters, speed, and load conditions change. The improved sensorless controller by removing the effect of the freewheel diode conduction is suggested. Some approaches use the zero crossing points of three-phase line-to-line voltages, so that they coincide to six commutation points. Although the commutation signals can be obtained without any phase shifter, the phase delay could not be considered and the multiple output transitions of the comparator may occur from the high frequency ripple or noise in the back EMFs. The zero-crossing point of the back EMF for generating proper commutation control of the inverter is calculated by sampling the voltage of the floating phase without using current and position sensors. Most sensorless techniques are based on back EMF estimation. when a motor is at standstill or very low speed, it is well known that the back EMF is zero to estimate a precise rotor position. Therefore, a specific start-up process in sensorless drive systems is required. The general solution to the problem is the open-loop start-up method named “align and go”. The procedure is to excite two phases of the three phase windings for a preset time. BLDC Motor Targeted by This Application The Brushless DC motor (BLDC motor) is also referred to as an electronically commuted motor. There are no brushes on the rotor and the commutation is performed electronically at certain rotor positions. The stator magnetic circuit is usually made from magnetic steel sheets. The stator phase windings are inserted in the slots (distributed winding) as shown in Figure (a) or it can be wound as one coil on the magnetic pole. The magnetization of the permanent magnets and their displacement on the rotor are chosen such a way that the Back-EMF (the voltage induced into the stator winding due to rotor movement) shape is trapezoidal. This allows the three phase voltage system with a rectangular shape, to be used to create a rotational field with low torque ripples. The permanent magnet rotor will then rotate to align to a specific position. With a known initial rotor position and a given
commutation logic, an open loop control scheme is then applied to accelerate the motor from a standstill. Although this technique can be applied to certain automotive applications.

Fig. 1 Block diagram

Fig. 1. Block diagram of sensorless control by using a hysteresis comparator. Smoothly from standstill without any position sensors by utilizing the inductance variation technique. This is done by monitoring the current responses to the inductance variation on the rotor position. Although these methods can detect a precise rotor position at standstill, they result in a complex control algorithm and an increase of the system costs due to an additional current sensor. Instead of the detection of current, only terminal voltage level is used for detection of the initial position of the permanent magnet. which requires the good reliability, a wide speed range from 3000 to 9000 rpm, fast start up, and high starting torque for the sensorless BLDC motor drive systems. To satisfy these requirements, this paper presents a sensorless control based on a hysteresis comparator of terminal voltage and a potential start-up method with a high starting torque. The hysteresis comparator is used to compensate for the phase lag of the back EMFs due to the LPF in order to determine the proper commutation sequence of the inverter according to the rotor position. Also, it can prevent multiple output transitions by high frequency ripples in the terminal voltages. The outputs of the three-phase hysteresis comparators become three commutation signals (Za, Zb, Zc), and then six gating signals can be generated through some logic equations. The operation of the a-phase hysteresis comparator is explained in Fig. 3. The filtered a-phase terminal voltage is applied to the inverting input, and the filtered c-phase terminal voltage is applied via R1 to the non-inverting input. A differential voltage of a-phase hysteresis comparator.

II. SENSORLESS CONTROL USING HYSTERESIS COMPARATOR

Fig. 1 shows the block diagram of a sensorless control by using a hysteresis comparator method. It consists for suppressing the high switching frequency ripples, hysteresis comparators for generating three-phase commutation signals, and a gating signals generator for generating six PWM signals. After sensing the three-phase terminal voltages, each of the three-phase terminal voltages is fed to suppress the high switching frequency ripple or noise. As only two phases of the BLDC motor are energized at any time, the back EMF can be measured from its terminal voltage in the period of an open phase. During the two-phase conduction period, the only difference between the back EMF and its terminal voltage is a stator impedance voltage drop, which may be considerably small compared with the dc voltage source. Therefore, Plots of phase lag to various rotor speeds under a variation of the cut-off frequency of the LPF. As the rotor speed increases, the percentage contribution of the phase lag to the overall period increases. The lag will disturb current alignment with the back EMF and will cause serious problems for commutation at high speed. The phase lag in commutation can produce significant pulsating torques in such drive which may cause oscillations of the rotor speed, and generate extra copper losses. In this paper, the cut-off frequency of the determined on 2.5 kHz by considering both the phase lag and harmonic distribution of the back EMF. The hysteresis comparator is used to compensate for the phase lag of the back EMFs due to the LPF in order to determine the proper commutation sequence of the inverter according to the rotor position. Also, it can prevent multiple output transitions by high frequency ripples in the terminal voltages. The outputs of the three-phase hysteresis comparators become three commutation signals (Za, Zb, Zc), and then six gating signals can be generated through some logic equations. The operation of the a-phase hysteresis comparator is explained in Fig. 3. The filtered a-phase terminal voltage is applied to the inverting input, and the filtered c-phase terminal voltage is applied via R1 to the non-inverting input. A differential voltage of a-phase hysteresis comparator.
The advanced angle $\theta_a$ is determined by the values of $n$, $V_{sat}$, and $V_p$, where $V_p$ is nearly proportional to the rotor speed. Fig. 4 shows plots of the angle $\theta_a$ for various rotor speeds under various resistance ratios, when the $V_{sat}$ is +1.2 V. The $\theta_a$ increases as the resistor ratio decreases or the rotor speed decreases. Therefore, the phase lag at the overall speed range can be compensated by adjusting the resistance ratio of the hysteresis comparator. The resistance ratio is determined to 1.2 in order that the gating signal can be nearly kept in phase with the back EMF when the motor is at the nominal speed, 6000 rpm. The hysteresis band can be calculated at +1 V because the $V_{sat}$ is +1.2 V and the resistance ratio $n$ is 1.2. Thus, if a peak of ripple voltage in the terminal voltage is within the hysteresis band +1V regardless of magnitude of the terminal voltage, it can prevent multiple output transitions at a hysteresis comparator by high frequency ripples in the terminal voltages. Fig. 2 shows the plots of the phase delay due to the LPF with 2.5 kHz cut-off frequency, the advanced angle by the hysteresis

Fig. 2. Plot of the phase delay, the advanced angle, and the phase shift after compensation.

Fig. 3. Timing diagram for commutation signals and three-phase gating signals relative to the terminal voltages. comparator with 1.2 resistance ratio, and the phase shift of the terminal voltage after compensating for the phase lag by the hysteresis comparator. It can be seen that although the phase lag by the LPF ranges from $-4.5^\circ$ to $-13^\circ$, the phase shift after compensation ranges only from $-3^\circ$ to $+2^\circ$. Thus, the maximum commutation delay at the 9000 rpm rotor speed is significantly reduced from $-13^\circ$ to $-3^\circ$. The logic equations for generating six gating signals of three phase PWM inverter from three commutation signals can be derived as

$$A^+ = (Za \oplus Zb) \cdot Za, \quad A^- = (Za \oplus Zb) \cdot Za \oplus (Zb \oplus Zc) \cdot Zh, \quad B^+ = (Zb \oplus Zc) \cdot Zh, \quad B^- = (Zb \oplus Za) \cdot Zb \oplus (Zc \oplus Za) \cdot Zc, \quad C^+ = (Zc \oplus Za) \cdot Zc$$

Based on the timing diagram for $a$-phase unfiltered terminal voltage, three-phase commutation signals, and three phase gating signals relative to the three-phase filtered terminal voltages are shown in Fig. 3. The $a$-phase filtered terminal voltage lags to the unfiltered terminal voltage by the phase $\theta_d$. Three commutation signals are advanced by the angle $\theta_a$ to

Fig-12(a) operation of Hysteresis comparator
the commutation points estimated by the three-phase filtered terminal voltages, and they can be compensated for the phase delay $\theta_d$ by the LPF. Because the waveform of the filtered terminal voltage is nearly the same as that of the filtered back EMF, the gating signal of each phase bridge of the inverter is almost in phase with the each phase of the back EMF. An automotive battery is usually lead-acid type to provide a 12-V volt system. A battery output voltage is widely varied according to the temperature, lifetime, and amount of charge. Because a battery is used as the dc voltage source of the PWM inverter, the peak of terminal voltage $V_P$ which is nearly the half of a battery output voltage, is also varied.

Fig. 4 Alignment of rotor position. (a) Switching states of the inverter. (b) Initial rotor position. (c)Block diagram

angle $\theta_E$ at changes with the battery output voltage, which might deteriorate the performance of sensorless control. Fig. 4 shows the circuit block diagram for adjusting the output voltage of hysteresis comparator $V_{sat}$ linearly to the battery output voltage change in order that the $\theta_E$ maintains constant. The circuit consists of an inverter amplifier with .01 amplification ratio, an inverting amplifier with minus unity gain for converting from $V_{sat}$ to $+V_{sat}$, and two buffers.

Fig-5 Inverting Comparator with Hysteresis

III. START-UP TECHNIQUE

When the motor is at standstill or very low speed, the back EMF is too small to estimate a precise rotor position. Therefore, a specific start-up process in sensorless drive systems is needed. A. Alignment of Rotor Position In the BLDC motor, only two phases of the three-phase stator windings are excited at any time by utilizing alternative six excited voltage vectors V1, V6, which are sketched in Fig. 4(b). That is why the current can flow into only two of the three windings and commutated every 60. of electrical angle. At standstill, the initial rotor position is aligned into one of the six positions that are determined by the six excited voltage vectors to energize two phases of the BLDC motor. As it is well known, the deviation of these voltage vectors is every 60. of electrical angle. The stator flux is not orthogonal to the rotor flux generated by the permanent-magnet at the
beginning of the start-up point if the conventional alignment method is used. Thus, the initial motor torque cannot obtain the maximum value at this time. Also, the stator winding incurs a high uncontrollable current by means of the fixed dc power supply and motor parameters. This might damage the stator winding of the motor if the active time for aligning a rotor position is too long. The conventional start-up method reveals some unexpected drawbacks that might degrade the performance of the BLDC motor. To overcome these restrictions, a simple start-up method not only to achieve the maximum starting motor torque but also to control the stator current is proposed. The principle of this technique can be remarkable as explained in Fig. 4. The current path and position of the initial voltage vector $V_i$ are shown in Fig. 4(a) and (b), respectively. Unlike the case in the conventional method where only two stator windings are excited, all three stator windings are energized in the case of the proposed start-up scheme by using a specific initial voltage vector $V_i(1,0,0)$. As the rotor is located between voltage vector $V_1$ and $V_2$, the voltage vector $V_3$ is orthogonal to $V_i$. It is chosen as the next applied voltage vector in order to achieve maximum starting motor torque at startup. It should be noted that the amplitude of the stator current for alignment of the rotor position can be easily adjusted by modulating the pulse width of the switching devices. Fig. 5 depicts the three-phase current responses of the BLDC motor, Fig. 6. Experimental setup. (a) Hardware configuration. (b) Photograph of the experimental setup.

BLDC PARAMETERS FOR VEHICLE FUEL PUMP APPLICATION

<table>
<thead>
<tr>
<th>Type</th>
<th>Y-connection, 4 pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>12V</td>
</tr>
<tr>
<td>Rated current</td>
<td>2.2A</td>
</tr>
<tr>
<td>Nominal Speed</td>
<td>6000rpm</td>
</tr>
</tbody>
</table>

Stator Resistance  0.19[ohm]

Stator Inductance  0.1095[mH]

Rotor moment of interia  1.9959e-006[Kg-m^2]

when turning on switch A+ and modulating the pulse-width of the two switches B. and C. at the same time. Fig. 6 shows minimum, maximum, and average values of the a-phase stator current with a variation of the duty cycles of PWM signals when a switching period $T_s$ is 100 $\mu$s. Obviously, the magnitude of the stator current can be easily governed by adjusting the duty cycle, which can be decided by considering the initial torque required at alignment. This method can prevent a surge of current that may damage the motor as in the case of utilizing the conventional method, and also it is robust with motor parameter changes. The motor may rotate reversely during alignment according to the rotor position before alignment. However, as a maximum reverse rotating angle is only 90 mechanical degrees, it does not have the influence on an oil pump operation.

Start-Up Procedure

After aligning the rotor position, the start-up procedure is considered for accelerating the BLDC motor from standstill up to a specific speed, 3000 rpm which is a minimum speed at the automotive fuel pump application. As the sensorless scheme is not self-starting, the motor should be started and can be brought to a certain speed at which the zero-crossing point of the back EMF can be detected. The I.f starting method, where the current is specified and maintained constant during accelerating the motor, is proposed at the back EMF-based sensorless control of a permanent-magnet synchronous motor. The v/f starting method is used at this paper, which is suitable for the BLDC motor drive.

The open loop starting based on v/f control is accomplished by producing the rotating electric field with a specific
relationship to the reference voltage in terms of a rotor speed. As the frequency is gradually increased, the rotor speed also increases. The magnitude of a reference voltage is adjusted as proportional to the rotor speed. A phase angle can be obtained from integrating the rotor speed and the pulse width of the gating signals is modulated with the reference voltage magnitude. The six PWM signals with 60° phase displacement are generated corresponding to the phase angle without any rotor position information. When the rotor speed reaches 3000 rpm, the back EMF can be sensed to provide the rotor position information and the system is switched to the sensorless control.

IV. EXPERIMENTAL RESULTS

A. Hardware and Software Configurations

The experimental system that was set up to validate the proposed method is shown in Fig. 6. The control system is implemented by a 16-bit PIC type 18F4431 operating with a clock frequency of 16MHz and the sampling interval is 50 μs for both the start-up and sensorless controls. As shown in Fig. 6, the PIC generates six PWM signals and also measures a rotor speed by using the three-phase commutation signals. The reference speed, rotor speed, and the reference stator voltage shown in the experimental results are converted into analog signals through a 12-bit 4-channel D/A.

![PWM signals and stator current response under aligning rotor position.](image)

Fig. 9. PWM signals and stator current response under aligning rotor position.

(a) At \( \omega_r = 3000 \) rpm. (b) At \( \omega_r = 6000 \) rpm. (c) At \( \omega_r = 9000 \) rpm. converter and displayed on an oscilloscope. Fig. 11(b) shows a photograph for the experimental setup. The plastic bottle is used as the oil tank, and an impeller is coupled to the rotor axis in the BLDC motor for pumping the oil. The oil flows through the inside of the BLDC motor, tube, and then back to the plastic bottle. The parameters of the BLDC motor used in the experimental studies are declared in Table I. Because a battery is used as the dc voltage source of the PWM inverter, the rated voltage of the motor is 12 V, which is the battery output voltage. The software flowchart is shown in Fig.7. At first, the rotor is aligned to the initial position for a time interval of 80 ms with constant duty cycle, and then the motor is accelerated to 3000 rpm by the proposed start-up method. When the rotor speed is greater than 3000 rpm, a sensorless control scheme for the BLDC motor is applied. The rotor speed can be calculated from measuring the one period interval of the a-phase commutation signal. After reading the states of the three-phase commutation signals, the six gating signals are calculated by using the logic. The pulse width of the upper three switches in the inverter is modulated with PWM duty ratio, and the six PWM signals are generated for driving the inverter.

B. Experimental Results

Some experiments are fulfilled to validate the proposed sensorless and start-up methods. Fig. 8 shows the a-phase and c-phase filtered terminal voltages, \( Z_a \), and a stator current at the light load condition when the rotor speed is 3000, 6000, and 9000 rpm, respectively. It can be seen that the \( Z_a \) is advanced to the crossing point between both terminal voltages by about 8.7° at \( \omega_r = 6000 \) rpm and about 10.7° at \( \omega_r = 9000 \) rpm, gating signals of the a-phase switching devices at \( \omega_r = 6000 \) rpm. Although the filtered terminal voltage lags the non filtered terminal voltage, \( A^+ \) and \( A^- \) both are nearly in phase with the actual terminal voltage.}

![PWM signals and stator current response under aligning rotor position.](image)

Fig. 9. PWM signals and stator current response under aligning rotor position.

(a) At 7% duty cycle. (b) At 15% duty cycle.

It is increased and the conducting period of the freewheeling diode is extended a little bit. The response of the a-phase stator current while aligning the rotor position. The switching device \( A^+ \) is always conducted and both switches \( B^- \) and \( C^- \) are modulated by 7% and 15% duty cycles, respectively. The
average values of stator current are about 0.8 and 4 A when the duty cycle is 7% and 15%, respectively.

Fig. 10. Start-up currents with a variation of the initial angle between stator and rotor fluxes under the light load condition.

(a) At initial angle = 90°
(b)At initial angle = 60°
(c) At initial angle = 0°

the magnitude of stator current can be easily controlled by the duty cycle for aligning a rotor position. Figs. 7 and 8 show the start-up current, the reference and rotor speeds with a variation of the initial angle between the rotor flux of a permanent magnet and the stator flux generated by the stator current at beginning of start-up mode under the light and heavy load conditions, respectively. The system is switched Start-up currents with a variation of the initial angle between stator and rotor fluxes under the heavy load condition.

(a) At initial angle = 90°
(b) At initial angle = 60°
(c) At initial angle = 0°

from the start-up mode to the sensorless control mode, when the rotor speed reaches at 1500 rpm. It can be seen that the startup current at the initial angle = 90° is lowest, and the start-up current increases as the initial angle decreases to 0° under both load conditions. The start-up current at the same angle is higher under the heavy load condition. In conclusion, when the start-up technique proposed by this paper is applied, it is able to start up the BLDC motor with the low current and the possibility for the start-up failure may be reduced. Fig. 9 shows the experimental results for responses of them reference and rotor speeds, reference voltage, and a-phase current in order to verify the start-up technique. At first, the rotor is aligned to the initial position for a time interval of 80 ms by adjusting the duty cycle to 15%. After then, the motor is accelerated to 3000 rpm by the proposed start-up method. Subsequently, a sensorless control scheme for the BLDC motor is applied for speeding up the motor to 6000 rpm. The start-up time is about 0.9s, which is acceptable for hydraulic oil pump application.

V. CONCLUSION

This paper presents a sensorless control based on a hysteresis comparator of terminal voltage and a potential start-up method with a high starting torque for hydraulic oil pump application. As the maximum commutation phase lag is significantly reduced from $-13^\circ$ to $-3^\circ$ by adjusting both the resistance ratio and the output voltage level of the hysteresis comparator, the commutation signal is nearly in phase with the back EMF. If a peak of ripple voltage in the terminal voltage is within the hysteresis band $+1$ V regardless of magnitude of the terminal voltage, it can prevent multiple output transitions at a hysteresis comparator by high frequency ripples in the terminal voltage. After aligning the rotor position for achieving the maximum starting torque, the BLDC motor accelerates from a standstill up to a nominal speed within 0.9 s and any fault it can be prevented and automatic restart. The magnitude of the stator current for aligning the rotor position can be easily controlled by modulating the pulse width of specific switching devices. Through the experimental results, it can be seen that the proposed sensorless and start-up techniques are ideally suited for the hydraulic oil pump application.

REFERENCES

[1] P. Champa, P. Somrisi, P. Wipasuramonton, and


TRAUMATIZED ARTICULAR CARTILAGE OF KNEE JOINT TREATED WITH BONE MARROW MESENCHYMAL STEM CELLS IN WISTAR ALBINO RATS

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Abstract  
The aim of this study is to find out the effect of bone marrow mesenchymal stem cells (BMSCs) in repairing the traumatized articular cartilage of knee joint in Wistar albino rats and to assess its healing potential by gross motor activities and micro anatomy.  

Materials and Methods:  
14 male Wistar albino rats were divided into 2 groups (Control and Experimental)  
  - Control group - Normal rats (4 rats)  
  - Experimental group - Normal rats (10 rats)  
Experimental group is further divided into 2 groups, Sub Group A - Injured articular cartilage without BMSCs (9 rats) and Sub Group B - Injured articular cartilage with BMSCs (5 rats). For experimental group rats left knee joint was selected randomly and it was opened and articular cartilage was damaged. In Sub Group B alone BMSCs was injected at the site of injury. Experimental groups rats were observed for gross motor activities on 3rd, 10th and 30th day and Histology study was also done at the same days.  

Results:  
Previous study revels BMSCs had positive impact in structural reformation of a damaged menisci in knee joint and this study shows rapid functional and structural improvement in rats treated with BMSCs than rats without BMSCs treatment.  

Conclusion:  
Bone marrow mesenchymal stem cells can be used as an alternative treatment for osteoarthritis in human beings.

Key words: Stem cells, BMSC, Multipotent cells, Adult stem cells, Wistar Albino rat, Obligatory differentiation cells.

Introduction  
Bone Marrow Mesenchymal Stem Cells (BMSCs) has ability to differentiate into either bone, cartilage, muscle, tendon, ligament, nerve, skin, fat cells, so a study was done to find out the effect of BMSCs in repairing the damaged articular cartilage of knee joint in Wistar albino rats. Articular cartilage was selected because age induced (degenerative) damage is more common to it in human beings, example Osteoarthritis. Osteoarthritis (OA) is the most common type of arthritis. Its high prevalence especially in the elderly made them disability and deformity. OA affects certain joints yet spares others. Commonly affected joints include cervical and lumbarosac spine, hip, knee and first metatarsal phalangeal joint (MTP). It was estimated that over 33 billion dollar are spent annually in the united states for osteoarthritis treatment.

OBJECTIVES  
- To assess the repairing potential of BMSCs in damaged articular cartilage.  
- To assess the functional status of the repaired articular cartilage by gross motor activities.  
- To assess the structural status of the repaired articular cartilage by micro anatomy study.

MATERIALS REQUIRED  
- 14 male Wistar albino rats  
- Cultured BMSCs from 1 young Wistar albino rat  
- Antibody CD 44 and CD 34  
- 1 ml syringe (12 nos)  
- Ketamine (500 mg, 1 vial)  
- Dissection kit  
- Hand glove  
- Dressing kit  
- Small stair case (15 steps)  
- Transparent glass cylinder (25 cm height × 10 cm breadth)

METHODOLOGY  
15 male Wistar Albino rats (100-200 gm weight) were taken, of these 1 young rat (6 months age) used for cell culture and rest 14 rats of age group above 1 year were divided into Control group and Experimental group.

1) Control group (4 rats).  
2) Experimental groups were divided into  
- Sub group A (5 rats) - Rats with articular cartilage damage deprived of BMSCs  
- Sub group B (5 rats) - Rats with articular cartilage damage treated with BMSCs

Rats was placed and maintained in same environment in the cage. Each cage was labeled with their group name and body weight. Food and fresh water was provided for rats.
**PROCEDURE**

Bone marrow was aspirated from 1 young rat under anesthesia. Aspirated bone marrow stem cells were kept in T flask containing CULTURE MEDIUM - Dulbecco's Modified Eagle's Minimal essential medium (DMEM). Cultured bone marrow mesenchymal stem cells were observed on the first, second and up to the sixth passage. The growths of the cells were slow and cell with process were seen. The second passage was done 20 days after the first passage. The time interval between the subsequent passages reduced. This showed that the cells adapted to the in-vitro environment. 6th passage cells were used for the transplant.

Bone marrow mesenchymal stem cells (BMSC) were separated from in vitro culture by adding Antibody CD44 and CD34. BMSCs were counted and sorted by flow Cytometer. Now BMSCs are ready for transplantation. Wistar Albino rats were divided into

1) Control group (4 rats).
2) Experimental groups were divided
   - Sub group A (5 rats) - Rats with articular cartilage damage deprived of BMSCs
   - Sub group B (5 rats) - Rats with articular cartilage damage treated with BMSCs

With permission from Institutional Animal Ethical Committee (IAEC/SMC/I/03/2013). All 14 rats were given gross motor activities training for a week before experiment. In operation theater with the help of veterinary surgeon following procedures were carried out. To make rats anesthetized, Ketamine 1 ml (conc.100mg/ml), Xylazine 0.5 ml (conc. 20 mg/ml) and 8.5 ml normal saline 0.9% were mixed. From this mixture 0.08 ml per 10 g body weight was administered intra peritoneally. In Sub group A and B left knee joint of rat was selected uniformly. Hair over left knee joint of rats were shaved using sterilized blade. Surgical incision was made on anterior aspect of knee joint. Patella bone along with ligamentum patellae was retracted. After reaching the articular ends of knee joint, articular cartilage and sub chondral bone (full thickness articular cartilage damage) along lower end of femur condyle was excavated and removed.

In Sub group A rats incision closed, allowed for natural healing. In Sub group B rats 1 ml of BMSCs injected at injured site and incision was closed. 1 ml contains 1-2 millions BMSCs (Rishbud et al 2008). Incision area was sutured with black silk suture and dressed with betadine. Check computerized tomography was taken for left knee joint to confirm whether articular cartilage was damaged or not and this was compared with the normal right side knee joint. Rate of recovery was observed in both groups. Microanatomy study and functional analysis (gross motor activities like walking, running, hind limb standing and stair climbing) were done at 3rd, 10th and 30th day for control and experimental groups rats. Using these findings recovery of articular cartilage was analyzed. After completion of this study Wistar albino rats used were given rehabilitation.

**EXPECTED OUTCOME**

Faster recovery was expected in Sub group B rats than in Sub group A rats in 3 to 4 weeks.

**GRADING FOR GROSS MOTOR ACTIVITIES**

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<th></th>
<th>Absent</th>
<th>Mild</th>
<th>Moderate</th>
<th>Marked</th>
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</tbody>
</table>

**RESULTS**

**GROSS MOTOR ACTIVITIES**

**Table 1: Control group (Normal rats) results.**

<table>
<thead>
<tr>
<th>S.NO</th>
<th>ACTIVITIES</th>
<th>DAY 3</th>
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<th>DAY 30</th>
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<tbody>
<tr>
<td>1.</td>
<td>Walking</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>2.</td>
<td>Running</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>3.</td>
<td>Hind limb standing</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>4.</td>
<td>Stair climbing</td>
<td>+++</td>
<td>+++</td>
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</tr>
</tbody>
</table>
Experimental groups:

Table 2: Sub group A (Rats with articular cartilage damage deprived of BMSCs treatment) results

<table>
<thead>
<tr>
<th>S.NO</th>
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<th>DAY 3</th>
<th>DAY 10</th>
<th>DAY 30</th>
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<tr>
<td>1.</td>
<td>Walking</td>
<td>+</td>
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<td>+</td>
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<tr>
<td>2.</td>
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<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3.</td>
<td>Hind limb standing</td>
<td>—</td>
<td>+</td>
<td>—</td>
</tr>
<tr>
<td>4.</td>
<td>Stair climbing</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 3: Sub group B (Rats with articular cartilage damage treated with BMSCs)

<table>
<thead>
<tr>
<th>S.NO</th>
<th>ACTIVITIES</th>
<th>DAY 3</th>
<th>DAY 10</th>
<th>DAY 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Walking</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>2.</td>
<td>Running</td>
<td>—</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>3.</td>
<td>Hind limb standing</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>4.</td>
<td>Stair climbing</td>
<td>—</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

From above result, Sub group B rats performed gross motor activities better than Sub group A rats from 10th day onwards.

On 30th day, Sub group B rats performed gross motor activities almost similar to normal rats.

HISTOLOGY RESULTS

Table 4: Results of Control group (Normal rats)

<table>
<thead>
<tr>
<th>Group</th>
<th>Day 3</th>
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<th>Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
<td>Well defined lacunae with mature chondrocytes were seen, Intervertebral matrix and territorial matrix was seen clearly and homogeneously stained. (Fig.1)</td>
<td>Well defined lacunae with mature chondrocytes were seen, Intervertebral matrix and territorial matrix was seen clearly and homogeneously stained. (Fig.1)</td>
<td>Well defined lacunae with mature chondrocytes were seen, Intervertebral matrix and territorial matrix was seen clearly and homogeneously stained. (Fig.1)</td>
</tr>
<tr>
<td>(Normal rats )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1

Table 5: Results of Experimental group - Sub group A

(Rats with articular cartilage damage deprived of BMSCs treatment)

<table>
<thead>
<tr>
<th>Group</th>
<th>Day 3</th>
<th>Day 10</th>
<th>Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>Chondrocytes were destroyed. Irregularities in matrix was observed (Fig.2)</td>
<td>Proliferation of chondrocytes was absent. Inflammatory cells started to appear in matrix. (Fig.3)</td>
<td>Many inflammatory cells were seen in matrix, chondrocytes were very few and marked matrix irregularity was observed. (Fig.4)</td>
</tr>
<tr>
<td>(Sub group A rats)</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Inflammatory cells seen in matrix of articular cartilage. Proliferation of chondrocytes were not seen.

Many inflammatory cells were seen in matrix
- Chondrocytes were very few
- Marked matrix irregularity was observed.

Experimental group- Sub group B
Table 6: (Rats with articular cartilage damage treated with BMSCs)

<table>
<thead>
<tr>
<th>Group</th>
<th>Day 3</th>
<th>Day 10</th>
<th>Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group (Sub group A rats)</td>
<td>Chondrocytes were destroyed. Irregularities in matrix was observed (Fig.5)</td>
<td>Proliferation of chondrocytes with homogeneus matrix seen. Few inflammatory cells also observed (Fig.6)</td>
<td>Well defined lacunae with mature chondrocytes seen, Interterritorial matrix and territorial matrix was seen with some irregularity. (Fig.7)</td>
</tr>
</tbody>
</table>

Figure 5 (3rd day image)
DISCUSSION:
In this study experimental group rats were compared with control group rats under following parameters like gross motor activities (walking, running, hind limb standing and stair climbing), histology study on 3rd, 10th and 30th day. Based on the performance of rats, gross motor activities were evaluated by grading. On comparing the result on 3rd day both sub group A and B rats did not perform gross motor activities. But on 10th day sub group A rats performed walking and stair climbing mildly, running and stair climbing was absent. It may be because of pain. On the other hand by 10th day sub group B rats performed all gross motor activities moderately. This may be due to rapid healing property of articular cartilage by bone marrow mesenchymal stem cells. By comparing 10th day results of both sub group A and sub group B rats, performance of rats treated with bone marrow stem cells was moderate. This implies BMSCs has rapid potential to reduce pain by its anti inflammatory property and by its differentiation property it was converted to chondrocytes and healed the damaged articular cartilage.

By 30th day sub group A rats dint perform gross motor activities. But on the same day sub group B rats performed functional activities ( gross motor activities) almost similar to control group rats.3rd day histology report of articular cartilage for both sub groups (A and B) shows damaged articular cartilage and irregularity in matrix, this was the reason for pain so both sub group rats dint perform gross motor activities. On 10th day sub group A rats micro anatomy report of articular cartilage shows inflammatory cells and no new chondrocytes were seen. Damage of articular cartilage was not repaired. Since the under lying pathology was not repaired rats cant do functional activities well. But in sub group B rats , active proliferation of chondrocytes observed and homogeneous matrix seen. Because, BMSCs injected in sub group B rats differentiated into chondrocytes and matrix components. Though articular cartilage in sub group B rats is healing better than sub group A rats by 10th day , sub group A rats performed gross motor activities moderately.

On 30th day sub group A histology report reveals many inflammatory cells and negligible amount of chondrocytes and marked irregularity of matrix , this made rats not to perform functional activities. On other hand 30th day histology report of sub group B rats revels well defined lacunae with mature chondrocytes , Interterritorial matrix and territorial matrix was seen with some irregularity . Rats of sub group B performed gross motor activities almost similar to control group rats because underlying pathology has recovered.Even on 30th day of Computed tomography results of sub group A rats, articular cartilage was not healed. But articular cartilage of sub group B

Histology results implies faster repairing potential of BMSCs structurally.

Note: Results were indicated by bold arrows in the corresponding figures

- Well defined lacunae with mature chondrocytes was seen
- Interterritorial matrix and territorial matrix was seen with some irregularity

Figure 6  (10th day image)

Figure 7  (30th day image)
healed moderately on 10th day itself and by 30th day marked
healing was observed due to the effect of BMSCs. Mauro
Krampera et al (2006) stated that Allogeneic goat BMSCs
heals damaged medial meniscus and anterior cruciate ligament
structurally in 10 goats. David et al (2005) stated that BMSCs
transplant heals articular cartilage damage but thinning occurs
later. These researchers confirmed the healing of articular
cartilage through histology study but in this study functional
status of healed articular cartilage was assessed with structural
back ground (Histology study).

CONCLUSION:
Articular cartilage is a type of hyaline cartilage and devoid of
blood and nerve supply.

Though articular cartilage is devoid of nerve supply, damage of
it is not sensed by patients until damage reaches sub
chondral bone which has ample of nerve endings.

On the other hand articular cartilage is not having the property
of self healing because of devoid of blood supply. So once
articular cartilage damage reaches sub chondral bone it starts
heals by replacement of articular cartilage by fibro cartilage.
Fibro cartilage can not provide firm structural and flexible
support as hyaline cartilage, so again it will get damage on
weight bearing.

Articular cartilage damage is seen more common in
osteoarthritis (OA), a degenerative condition occurs mainly
due to wear and tear of articular cartilage and also in various
knee pathology. People with OA become disabled due to pain
and deformity developed at later stage of this disease. To
overcome all these problems regeneration of articular
cartilage by BMSCs in the damaged area of it gives a great
permanent remedy for people suffering from articular cartilage
disease. Rosa McCarty et al (2005) stated that BMSCs
transplantation lead to chondrogenesis in damaged cartilage. Ali Mobasher et al (2011) stated that BMSCs may
used as treatment option for Arthritis. So BMSCs may be used
as a treatment option for articular cartilage damage in OA.

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