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Mission Statement

The mission of **Sukkur IBA Journal of Emerging Technologies (SJET)** is to provide a premier interdisciplinary platform to researchers, scientists and practitioners from the field of engineering in particular, electrical, electronics, renewable and emerging engineering fields for dissemination of their finding and to contribute in the knowledge domain.

Aims & Objectives

Sukkur IBA Journal of Emerging Technologies (SJET) will publish and encourage the submission of critically reviewed manuscripts on the cutting edge research in the field of emerging engineering technologies.

The objectives of **SJET** are:

1. To bring new engineering ideas, research and findings on a single platform.
2. To integrate interdisciplinary research for technological sustainable solution.
3. To provide scholarly platform to connect academia and industries for socio-economic development.

Research Themes

The research focused on but not limited to following core thematic areas:

Renewable Energy Sources and Storage:

- Solar energy system fabrication and construction of advanced fuel cell technology
- Designing and analyzing smart hydro and wind energy systems
- Developing systems for biomass and bio-fuels
- Energy management and storage
- Energy devices and materials
- Energy harvesting for wireless and body sensor networks
- Energy efficiency and policies
- Energy devices and materials

Power Systems and Smart Grids:

- Power Quality Issues and solutions
- Micro grid systems and their Integration Problems
- Design control and management
- Energy management and Environmental issues
- Hybrid power system
- Distributed and co-generation systems
- Power market and power system economics

Electrical Machines and Adjustable Speed Drives:

- AC and DC machines and drives
- Sensor-less control
- Piezo and electrostatic actuators
- Machine design and equipment training
- Maintaininace and fault diagnosis
- Bearing less driving technologies

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Power Electronics and its Application:

- Hard-switching and soft-switching static converters
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- Emerging topologies
- Simulation and control power converters
- Power factor correctors
- Active filters and total harmonics distortions analysis
- Optoelectronics and photonic devices
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- Applications of power electronics in home appliance

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- Power Integrated circuits (PIC)
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- Power system transient modeling, simulation and analysis
- Electromagnetic transient programs (EMTP)
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- Nanomaterials
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- magnetic sensors
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- Amorphous
- Polycrystalline monocrystalline silicon, nanomaterials
- Synthesis of nanomaterials, composite materials
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- Electronic thin films and integrated devices
- Engineering materials
- Solid and structural mechanics

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Sukkur IBA University has been imparting education with its core values merit, quality and excellence since its inception. Sukkur IBA University has achieved numerous milestones in a very short span of time that hardly any other university has achieved in the history of Pakistan. The institute continuously being ranked as one of the best Institute in Pakistan by Higher Education Commission (HEC). The distinct service of Sukkur IBA University is to serve rural areas of Sindh and also underprivileged areas of other provinces of Pakistan. Sukkur IBA University is committed to serve targeted youth of Pakistan who is suffering from poverty and deprived of equal opportunity to seek quality education. Sukkur IBA University is successfully undertaking its mission and objectives that lead Pakistan towards socio-economic prosperity.

In continuation of endeavors to touch new horizon in the field of Engineering and Emerging Technologies, Sukkur IBA University publishes an international referred journal. Sukkur IBA University believes that research is an integral part of modern learnings ad development. **Sukkur IBA Journal of Emerging Technologies (SJET)** is the modest effort to contribute and promote the research environment within the university and Pakistan as a whole. SJET is a peer-reviewed and multidisciplinary research journal to publish findings and results of the latest and innovative research in the fields. Following the tradition of Sukkur IBA University, SJET is also aimed at achieving international recognition and high impact research publication in the near future.

Prof. Nisar Ahmed Siddiqui
Sitara-e-Imtiaz
Vice Chancellor
Sukkur IBA University
Patron **SJET**

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Editorial

Dear Readers,

It is immense pleasure to present you the first issue of Sukkur IBA Journal of Emerging Technologies (SJET). Sukkur IBA University firmly believes in research environment and has provided a platform for the intellectuals and researchers to share knowledge and new findings on emerging trends in various research areas to solve the difficult technical problems related to the technological advancements in response to the demands of the times. The SJET provided interdisciplinary platform to researchers' community to collaborate, co-innovate and instigate efforts to break the technological barriers. This journal provides the opportunity to gain and present authentic and insightful scientific & technological information on the latest advances in the field of emerging technologies.

The SJET provides invaluable source of information and enables the interested researchers to access the original information they are seeking. The manuscripts submitted in SJET have been followed by double-blind peer-review process, which addresses key issues in the field of emerging engineering technologies. The SJET has endorsed highly standards which are prerequisite for publishing high quality research work. This journal manifests into eco-system for the academician and engineers work together in the pursuit of excellence & innovation, that is why the editorial board of SJET is comprises of academic and industrial researchers from various advanced countries. The journal has adopted Open access policy without charging any publication fees that will certainly increase the readership by providing free access to a wider audience.

On behalf of the SJET, I welcome the submissions for upcoming issue (Volume-2, issue-1, January – June, 2019) and looking forward to receive your valuable feedback.

I hope this journal will make a difference in our perspective and choice of research.

Sincerely,

Dr. Saeed Ahmed Khan
Chief Editor
SJET

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Contents

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A Novel Asymmetric Three Phase Multilevel Inverter with Reduced Switches

Mafaz Ahmed [1],Tila Muhammad[2],Rafi Uzman[3],Omais Khan[2]

Abstract:

Multilevel inverters (MLI) are the most reliable and suitable inverters for medium and high-power applications. These inverters reduce the total harmonic distortion. There exist many types of single and three-phase multilevel inverters which are used in industries. The main issue of these multilevel inverters is use of an excess number of switches, which introduces the in-system losses, complexity of circuit, size, and cost etc. There are many novel topologies of multilevel inverter which are addressing the same issues. This paper anticipated a new topology of asymmetric cascaded multilevel inverter (MLI). This novel topology can be used for single, three and multi-phase inverters and is most suitable for medium and high-power applications. To demonstrate the working of this novel topology in detail, its modes of operation are also explained. The validity of this inverter is tested for both resistive and inductive load. Due to the utilization of very limited switches, gate drivers and DC voltage sources, it is found that this topology is low cost, simple and efficient inverter.

Keywords: *Three phase multilevel inverter, Cascaded Multilevel Inverter, medium power, and high-power converters, Asymmetric Multilevel Inverter, Reduce switches*.

1. Introduction

Multilevel inverters (MLI) synthesize several DC voltage sources to produce staircase output having desired multilevel waveform [1-3]. Multi-level inverters are the modification of basic bridge inverters. They are normally connected in series to form stacks of level. Multilevel inverters (MLI) are widely used in medium power and high-power applications [4-6]. There is a lot of interest in multilevel inverters due to its usage in renewable energy resources [7]. Total harmonic distortions (THD) in MLI are low. That is why they are also preferable for industrial motor drives [8]. MLI are also used in flexible transmission system, where it is a core component of STATCOMs.

Multilevel inverters (MLI) exist as single, three and multi phases in industry. In this paper, we targeted three phase inverters. Three classical topologies of MLI are: (a) neutral point clamped MLI (NPC) [9], (b) cascaded H-bridge MLI (CHB) [10, 11], and (c) flying capacitors MLI (FC) [12]. Type (a), Cascaded H-bridge is the most favorable among these three classical topologies for applications requiring many levels. Type (b) neutral point clamped Inverter (NPC) are used in applications requiring lesser number of output levels. Type (c) Flying capacitors topology has the advantage of modular structure, minimum

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requirement of DC voltage sources and low-cost components. Due to large interest in cheaper, reliable, and better quality multilevel inverters a lot of research is ongoing to design optimum multilevel inverters. Research areas like reducing numbers of switches and others power components in converters design is one of the most interested area for researchers [1, 8, 13, 14], while number output voltage levels of the inverter are not disturbed.

By growing the number of output levels in inverter, the harmonic distortion reduces, and hence output waveform quality improves. With increase of output levels, the number of switches also increases dramatically. The increase number of switches reduces efficiency, while increases size, complexity, and cost of the system. In this research, a novel asymmetric MLI topology is anticipated to achieve desired output levels with fewer number of switches and gate drivers. A work like this research is listed in [10, 15, 16]. The proposed design is based on a modified version of cascaded topology; therefore, hereafter discussions is restricting to the cascaded topologies only.

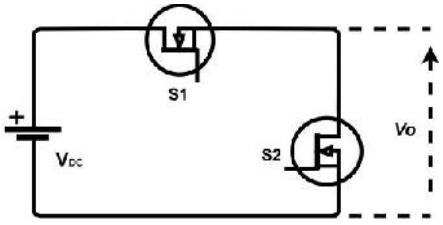

Fig. 1. The unit cell of MLI

The number of bridges required in the CHB inverter is proportional to the number of output staircase levels. The mathematical relationship between number of levels (NL) and number of bridges (NB) required is given as:

$$N_B = \frac{N_L - 1}{2} \qquad (1)$$

NL can be any odd integer greater than three. Similarly, the total number of switches required NT are:

$$N_T = 4N_B \qquad (2)$$

By combining equations 1 and 2 number of required transistors can also be represented as:

$$N_T = 2(N_L - 1) \qquad (3)$$

The topological structure of MLI must have the capability to deal with the following points

- Capability to sustain high input voltage such as HVDC
- MLI must have less switching devices as possible.
- Low switching frequency for MOSFET's/IGBT's due to multilevel approach.

Similar work is presented in [15] which also addressed the importance of reduction of switches and anticipated a novel MLI with reduced number of switches. As proposed in [15] it is concluded that for addition of a new source to increase a positive and a negative level two transistor switches are required in the case of symmetric MLI. For the ease of access, the unit cell used in [15] to increase 2 levels of the output is depicted in figure 1. It is clear from the figure 1 that S1 and S2 are the required two switches while the Vdc is the voltage to be synthesis with the output.

A similar work is also presented in [16] where the proposed inverter also synthesis two levels with a single switch with the output but the transistor used in that topology is a bidirectional switch, where two transistors are connected back to back. While comparing the inverter proposed in this research is using only unidirectional switch along with only an additional switch.

In the similar way the unit cell used in this research (Asymmetric cascaded MLI) is consist of a voltage source, a transistor and a diode as shown in Figure 2. Hence one transistor in the inverter of [15] is replaced with a diode. The replacement of transistor with diode is giving good results in many aspects. The most prominent advantages are no turn ON and OFF of diode are required. Therefore, it decreases the complexity of

control signals. The diode is more robust than transistors. High power rating diodes are usually more easily available than transistors, it also decreases the cost of inverters because usually diodes are cheaper than transistors. Furthermore, the diodes do not need any driver circuitry, therefore, it further reduces the cost, size, and complexity of the circuit.

This proposed design is further explained in detail in the section II of this paper.

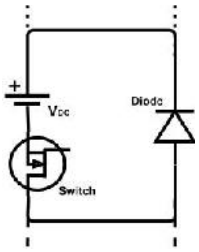

Fig. 2. Unit cell of the proposed Asymmetric cascaded MLI

Table I shows comparison between classical cascaded topology, Diode clamped MLI topology and proposed novel MLI topology. The number of switches is quite less than those of the two other topologies as shown in table I. Number of levels increases with the number of switches increases drastically. On the other hand, novel MLI topology requires only one switch to introduce new level.

According to the above discussion and calculation the following table shows the relation between the classical cascaded H-Bridge inverter, the reduced switches inverter discussed in [15] and proposed multilevel inverter topology.

This research is organized such as, section 2 explains the proposed design. Section 3 explains the modes of operation, while in section 4 the design is validated using simulations. In section 5 the modulation technique has been discussed. In section 6 the design is tested for inductive load. In section 7 hardware implementation has been discussed section 8 the conclusion has been made and at last future work has been proposed.

2. PROPOSED MULTILEVEL INVERTER TOPOLOGY

This research proposed a new topology of asymmetric cascade MLI in which two levels (one positive and one negative) are added to output by the addition of a single transistor and diode as shown in Figure 3. Although this topology is general and can be extended to any levels here just for simplification we limited our discussions to 5 levels. For five levels output our topology requires an H- bridge (consisting of four transistors), one diodes and one transistors (along with anti-parallel diode) switches as compared to classical inverter that requires 8 transistors, this new design significantly reduces the number of required switches and the number of gate drivers along with another required circuitry. Comparison has been shown in table II.

TABLE I. Comparison of Topologies with reduced switches

No. of levels	Classical Cascaded H-Bridge Topology A		Diode Clamped Topology B		Proposed Reduced switches Cascaded Topology B	
	Number of transistors	Number of drivers	Number of transistors	Number of drivers	Number of transistors	Number of drivers
5	8	8	8	8	5	5
7	12	12	12	12	6	6
11	20	20	20	20	8	8
13	24	24	24	24	9	9
N	2n-2	2n-2	n+3	n+3	(n-3)/2+4	(n-3)/2+4

TABLE II. Comparison of Topologies with reduced switches

	Diode Clamped MLI	Flying capacitor MLI	Cascaded MLI	MLI with Reduced Switches
No. of Switches	8	8	8	5
No. of Clamping diodes	8	0	0	1
No. of Floating capacitors	0	8	0	0
No. of dc bus capacitors	4	4	2	2

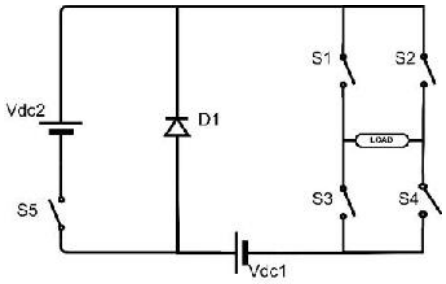

Fig. 3. Asymmetric cascaded MLI

The number of transistors switches (NT) for any desire levels can be found as:

$$N_T = \frac{N_L - 3}{2} + N_B \qquad (4)$$

Where NL is the number of desired staircase output levels and NB is denote as the number of transistors in H-bridge.

To generate multi-level output the design requires isolated DC voltage sources and diodes. These isolated DC sources to synthesis and number of extra diodes is a function of output levels which can be formulated as:

$$V_{DC} = \frac{N_L - 3}{2} + 1 \qquad (5)$$

$$N_{DL} = \frac{N_L - 3}{2} \qquad (6)$$

$$N_{FD} = N_T \qquad (7)$$

Where, VDC stands for isolated DC voltage sources and NDL represents number of diodes requires for addition of levels to the output. In addition, freewheeling diodes (NFD) require are also given by equation 4.

2.1. Case Study: Nine Level Inverter

In this section, a single phase of the proposed design is explained by considering the case of nine levels output. By using equations 4, 5, 6 and 7 we found number of transistors, freewheeling diodes. Figure 3 shows the circuit diagram of the five levels MLI.

The design is validated by using simulations presented in Section IV which is

TABLE III. Switching Scheme

S1	S2	S3	S4	S5	Output Voltage
ON	OFF	OFF	ON	OFF	Vdc1
ON	OFF	OFF	ON	ON	Vdc1 +Vdc2
OFF	OFF	OFF	OFF	OFF	0
OFF	ON	ON	OFF	OFF	-(Vdc1)
OFF	ON	ON	OFF	ON	-(Vdc1 +Vdc2)

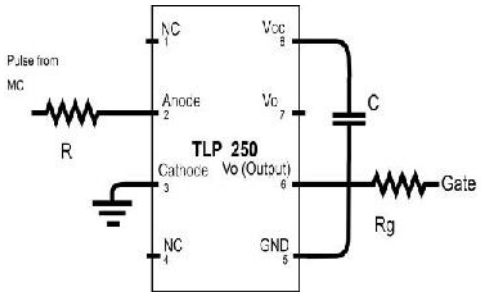

Fig. 4. Driver Circuitry

also tested for inductive load presented in section VI. The working principle of the design is explained in next section.

2.2. Gate Circuitry

TLP 250, like other drivers has an input stage, output stage and the input power source. It is optically isolated driver, means that input and output are optically isolated. Figure 4 shows the diver circuitry.

3. WORKING PRINCIPLE

Table III shows the switching scheme of the Novel single phase five level asymmetric cascade MLI topology, given in figure 3. The working of the design is explained by using five modes, where positive half cycle is explained by using modes 0 to 2. Negative cycle is explained by using modes 3 to 4.

3.1. Positive Half Cycle

The positive half cycle is given in figure 5. To achieve the waveform of figure 5, the entire procedure and switching scheme is divided into three different modes, which are discussed below in detail with heading Mode 0 to Mode 2.

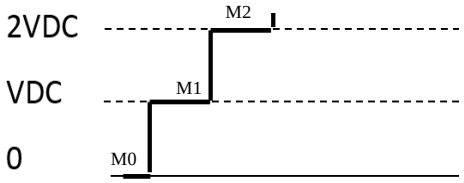

Fig. 5. Positive half cycle

Mode 0: In this mode no switch is conducting, so the output voltage is V=0 which is shown in Figure 6 and its output is highlight with M0 in Figure 5.

Mode 1: In this mode Switch 1 and Switch 4 are in ON state, along with diodes 1 that is in forward conducting mode. The voltage source VDC1 is connected to load as shown in Figure 7 and figure 5 shows first stair in output appears as M1.

Mode 2: In this mode of operation, diode D1 is turned off while switch 5 has been turned ON in addition to previous switches. In this mode two voltage sources VDC1 and VDC2 add up and are connected to the load as shown in Figure 8 and output stair is highlighted with M2 in Figure 5.

Mode 2 completes the positive half cycle; the next positive half cycle is generated by reversing the aforementioned modes in which the output level decreases gradually and at last reach to zero level in which no source is

connected to the load using transistors. In this case, if the load is inductive, the stored energy can be sent back to the sources using freewheeling diodes.

3.2. Negative Half Cycle

Similarly, to the positive half cycle the level of the inverter increases in negative region by adding the DC voltage sources with load in reverse polarity. The output levels are shown in Figure 12. The whole process and switching scheme utilized in generating of negative half cycle is explained in detail in Mode 3 and Mode 4.

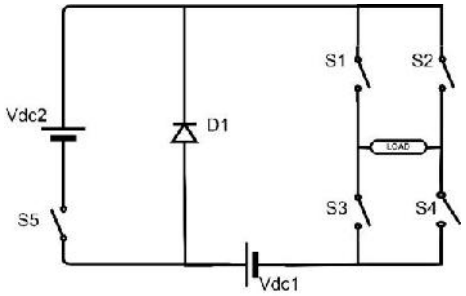

Fig. 6. Mode 0

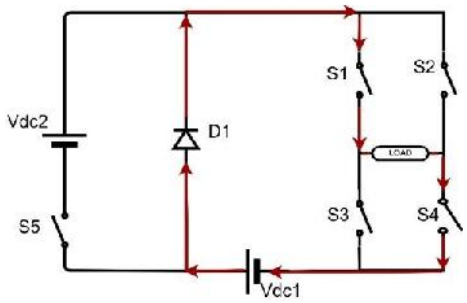

Fig. 7. Mode 1

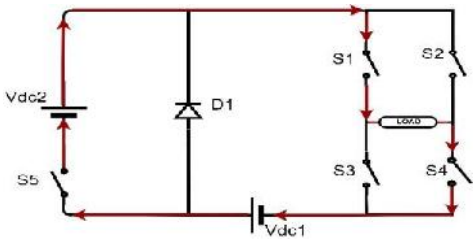

Fig. 8. Mode 2

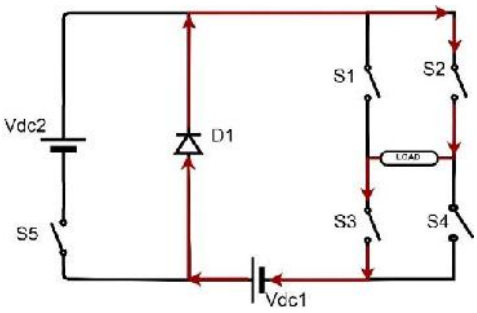

Fig. 9. Mode 3

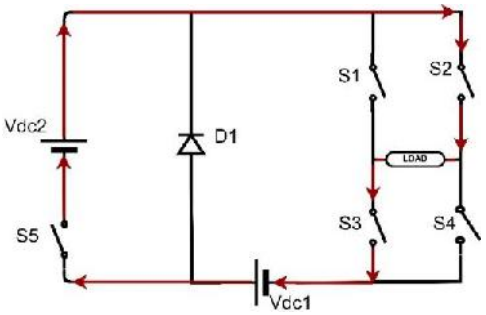

Fig. 10. Mode 4

Mode 3: In this mode Switch 2 and Switch 3 are turned ON, while the diode 1 is in forward conducting state as shown in Figure 9 with this switching scheme the voltage source VDC1 appears across the load with negative polarity that is Vout = -V as shown in Fig 12, which is highlighted as M3.

Mode 4: In this mode, switch 5 is conducting, while the diode D1 is turned OFF and the remaining switches are in same state of conduction as that of Mode 4. So, the sum of DC voltage sources VDC1 and VDC2 connect to the load with negative polarity as shown in figure 10 and figure 12 shows the output as M5.

Mode 4 completes the negative half cycle of the staircase output; the next negative cycle is generated by reversing the modes in which the output level decreases gradually from negative peak value and at last reach to zero level in which no DC voltage source is connected to the load using transistors.

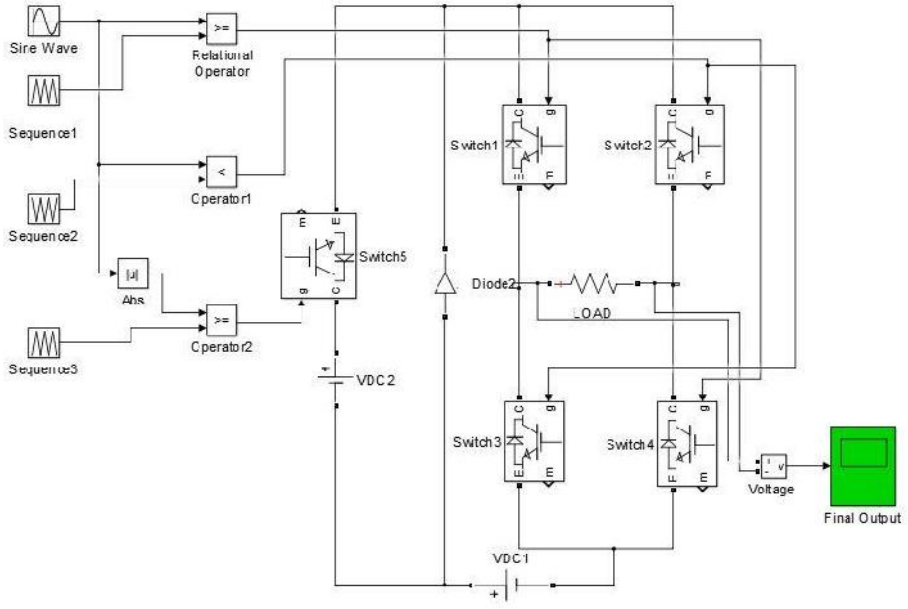

Fig. 11. Single phase of Five level multilevel inverter

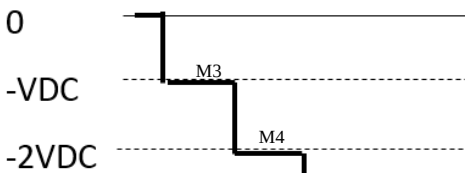

Fig. 12. Negative half cycle of output

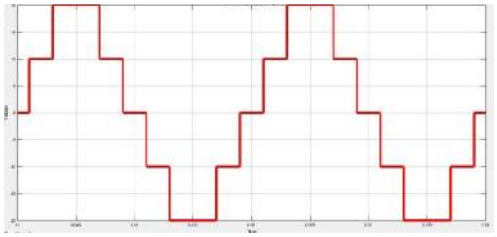

Fig. 13. Simulation results five level single Phase Multilevel Inverter

All the above 5 modes discussed for 5-level multilevel inverter. Simulation results for 5-level MLI has been discussed in the coming sections.

4. SIMULATION

The novel MLI design has been validated by using MATLAB/Simulink toolbox. Simulation has been performed for the design given in Figure 3 for generating five levels output. Figure 11 shows the simulation model of proposed novel single phase MLI. In the simulation for five level MLI, five switches and one diode are used. The staircase waveform for resistive load is shown in the fig 13. This makes the output wave form to look like sine wave, the width of the output stairs is different.

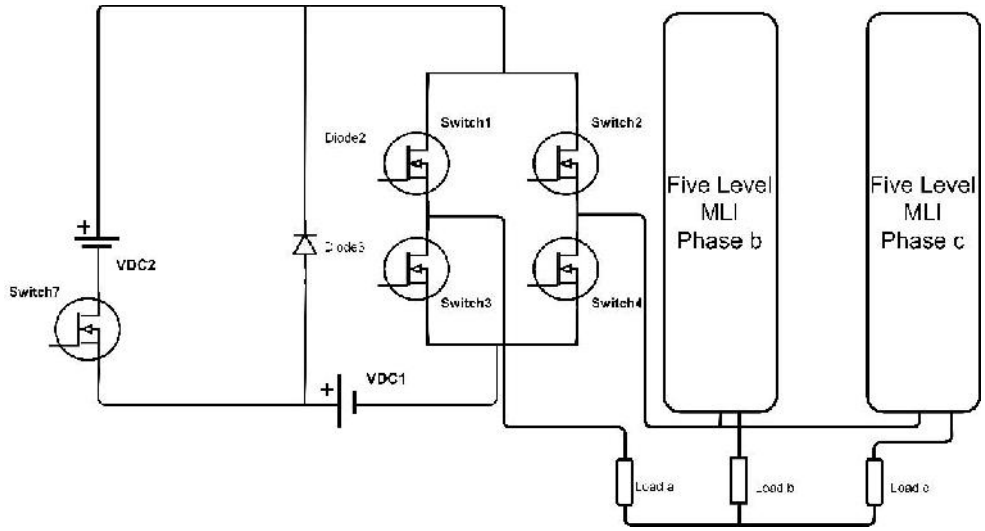

Fig. 14. Three Phase Asymmetric cascaded MLI

In the similar way, proposed design of five-level three phase multilevel inverter has also been implemented using MATLAB Simulink. The three-single phase MLI of Figure 14 are connected in parallel to generate 3-phases as shown in Figure 16.

The simulation results are shown in Figure 16 is the out from phase to neutral.

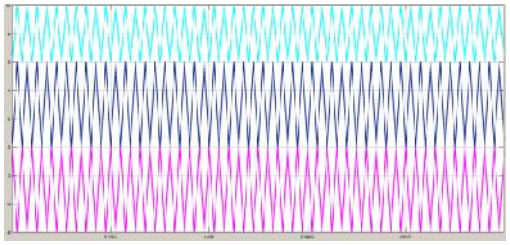

Fig. 15. Carriers Signals for MLI

5. SINEWAVE PULSE WIDTH MODULATION (SPWM)

To regulate the output and control different parameters of inverters modulation techniques are used [20]. There are many types of modulation techniques for the modulation of the proposed MLI [21-22]. Here to verify the validity of modulation in the proposed MLI, shifted carrier based SPWM is selected and used. Alternate Phase opposite Disposition

(APOD) has been used for modulation as shown in figure 15. In APOD modulation all carriers are in phase that are above the zero-reference level but are opposite to triangular signals below zero reference. Normally four triangular signals will be required, but for this topology, three triangular signals are sufficient. Switch 5 is ON in both intervals (+ive and -ive), So, it required one triangular signal.

The test is conducted by using carrier frequency 20 kHz while the modulated frequency is 50 Hz and for nine level MLI.

Here the carriers are the triangular waves while the modulated signal is a reference sine wave. The carriers are compared with the reference sine wave and the desired switching pattern of transistor gate signal is generating. The modulated output wave form for single phase is given in Figure 17 and for three phase outputs is shown in figure 16. Figure 18 shows the harmonic analysis of MLI. The total harmonic distortion is 5.82%.

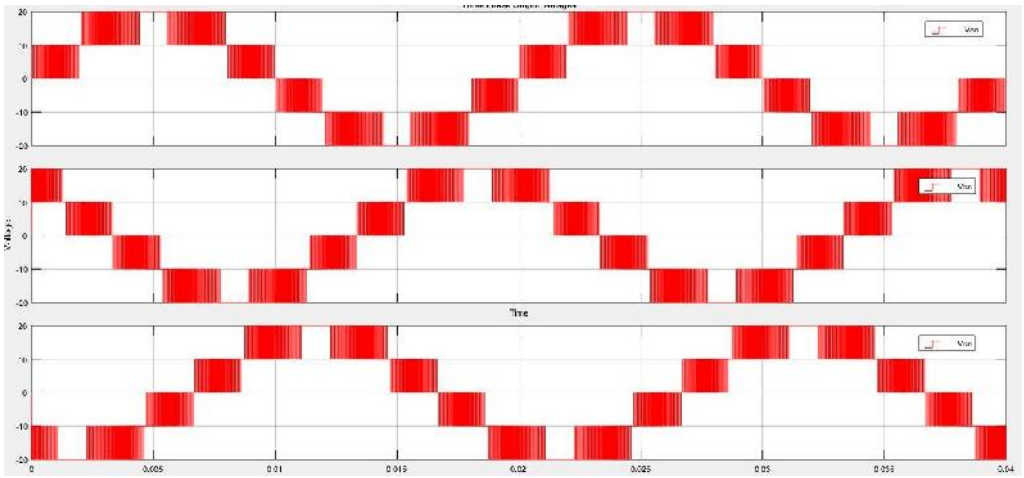

Fig. 16. Three Phase MLI SPWM Modulated Output

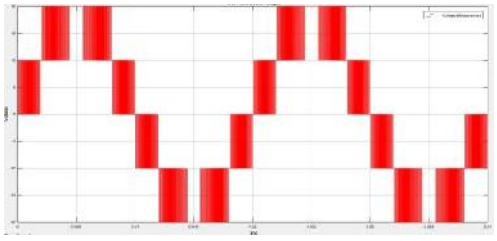

Fig. 17. SPWM modulated output waveform

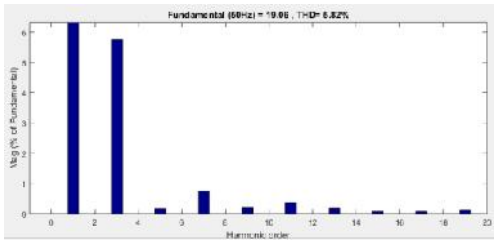

Fig. 18. Hamonic Analysis

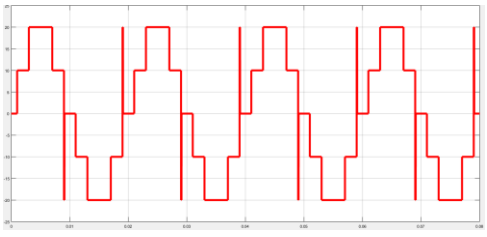

Fig. 19. Output wave with inductive load

6. VALIDITY FOR INDUCTIVE LOAD

The validity of the proposed MLI is also tested for inductive loads. Fig 19 shows the simulation model with inductive load. There are anti-parallel diodes with each transistor which is working as the freewheeling diode when the reverse e.m.f. produces during switching in the presence of inductive load.

7. HARDWARE IMPLEMENTATION

A prototype has been developed for the proof of concept of proposed MLI. This prototype of inverter is given in Figure 20. The triangular and reference sine wave are generated by using op-amp ICs while for the comparison of the two signals comparator ICs are used. Probe has been set with 10x and vertical sensitivity is 1 volt/cm.

$$V_{p-p} = 50\ V$$

$$V_p = \frac{50}{2} V$$

$$V_p = 25\ V$$

Figure 20 shows the three-phase implementation of five level multilevel inverter. Second shelf has the push pull inverter for low voltages (24 low voltage supplies). Third shelf has the circuit for

switching signals. The output wave of the prototype is given in the Figure 21. Due to unavailability of three channel oscilloscope only single-phase output is given in Figure 21.

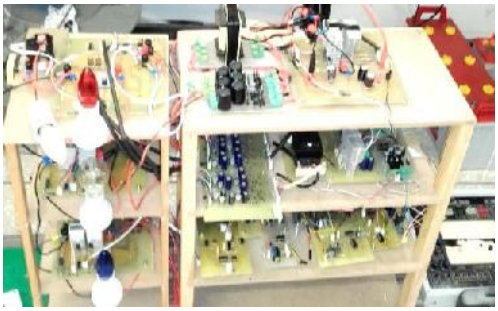

Fig. 20. Three phase multilevel inverter prototype

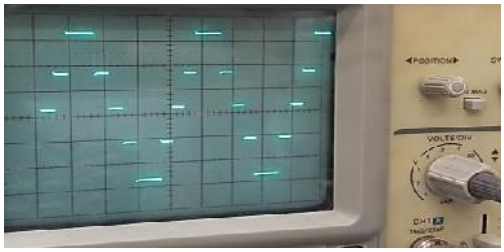

Fig. 21. Single phase output of MLI prototype

8. CONCLUSION

The Novel topology of an asymmetric cascaded MLI has been proposed that has less number of switches. The design reduces switch losses and is more cost effective. Therefore, the number of driver circuit is also reduced, as well as low dv/dt stress on individual switch and switching losses is reduced. As the number of power components decreases, the cost decreases, the design becomes simpler and size of the system also reduces. The design can be used to generate output waveform with any desired number of levels. The proposed design has been validated by simulations considering resistive as well as inductive loads.

9. FUTURE WORK

More modulation techniques like SHEPWM, SHMPWM, etc. can be applied to this novel topology to further reduce total harmonics distortion THD.

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Design and Control of Unmanned Underwater Vehicle

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Abstract:

Unmanned Underwater Vehicles (UUV) are the robots that are used to monitor underwater environment at remote distance, either for inspection of underwater wreckage or for surveillance of underwater environment. Any such robot due to harshness of environment conditions needs a robust watertight design and requires various sensors for effective environment monitoring. The entire UUV structure is comprised of the vehicle, which is linked with operators on top of the surface by a set of cables that hold relevant cables for data and power communication. In this context, a lightweight underwater vehicle was designed using PVC (Polyvinyl Chloride) pipes and equipped with brushless DC motors, electronic speed controller, relay module, sonar, claw arm and Camera. It can navigate in six directions (up, down, left, right, forward, backward) and camera allows underwater surveillance of the environment, with sonar helping to indicate the target depth. The designed UUV can also perform basic pick and place task using a claw arm and is remotely operated using a joystick controller. Overall, the designed UUV prototype has shown its potential capabilities for underwater surveillance and environment monitoring through practical demonstrations.

Keywords: *Automation; ROV; Sonar; joystick; manipulator;Arduino.*

1. Introduction

The inventions of the UUV's were designed for underwater surveillance and to explore underwater life. it is widely used by navy for underwater inspection and it is also widely used by civilians in oil industries. Sometimes it's also known as underwater drones. Such vehicles can act as the eyes of undersea fleet. These are most recent demonstration of such vehicles, replacing divers to do work in the ocean. These vehicles, also known as Deep Submergence Vehicles (DSVs), were designed to go deeper than divers. These were configured for ocean exploration, science, rescue, and survey [1, 2]. It is fundamentally a tethered submerged vehicle which consent the robots functioning to continue in comfy surroundings although it works in the perilous surroundings below. The entire UUV structure is linked with operators on the facade by a set of cables that lug electrical power, video and information signals reverse and forward among the

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machinist and the vehicle. UUVs are relatively small, tethered, and unmanned vehicle that are able to work solely underwater within the handled and sustained ability [4]. Unmanned underwater vehicle varies in design modeling according to the desired operational depth and task. Mainly Autonomous Underwater Vehicles (AUVs) can be able to function near 200 m or consequently, with a little working ahead of 5000 m. Autosub-2 of the UK is usual of the intend of lots of AUVs. Long-range gliders (Simonetti, 1998) can also be considered as AUVs, although for the purposes of these review they are excluded because of the high power and payload-space requirements of current auditory instruments; gliders as well have limited straight actions which would build logical surveying challenges [5]. Due to the huge technical improvements obtained in past decade, it is probable to utilize robot's vehicle for undersea examination. In this approach, Remotely Operated Vehicles (ROVs) have been used carefully in the investigation of subsea phenomena as well as in the assemblage, examination and repair of offshore structures. Throughout the completion of a firm task with the robotic vehicle, the operator needs to observe and manage a number of parameter. If, for example, the adjustment to the position of ROV are made automatically, the precision will be greatly increased as compared to an observer controlling it manually [7-10]. This paper present the design of a UUV through an innovative display of thrusters with dynamical planned system in desire to be used in replication and manipulative of controllers. Finally, design and structure of prototype of the planned UUV, with brushless DC motors arrangement of the current work is presented. The compensation of using a proper arrangement of brushless DC motors is scheduled as under [3]. Reducing the number of required motors, at least six motors through propeller are essential to manage the UUV in its six degrees of freedom (DOF), while by brushless DC motors just three or utmost four DC brushless motors are essential in order to give the essential pressure. Materials Inventory of latest assembly being used in autonomous submerged robots will persistently increase. In addition, aluminum with carbon fiber can be utilized for such deep sea vehicles. In this prototype the PVC (Polyvinyl chloride) pipes are used in the assembly. These materials permit the UUV to be both lightweight and neutral buoyant, and to resist opposing friction. An example of underwater vehicle with similar materials is Deep glider, capable to submerge up to 6 km [4].

2. Control System

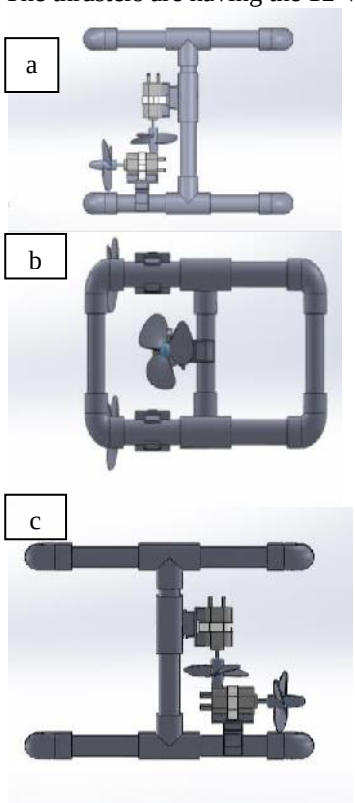
The control system designed for this UUV is simple and low cost. The vehicle is controlled on the front end by a PS2 joystick programmed with Arduino Nano as a master controller, which includes electronic components such as power regulators, live screen, battery bank and interfacing keys. Master controller via tether using serial communication (I2C) controls the slave controller. The designed assembly of UUV lying on simple design reduces drag, which improves the underwater manipulative performance of the vehicle. A proportional integration and derivation (PID) controller has been implemented effectively in this approach. The control system provides the controllable and desired thrust power to the designed vehicle. Different control methods of unmanned submerged vehicle are shown in Table I.

TABLE I. Control methods with restriction

Control method	**limitations**
PID	Can't energetically recompense instead un-modeled robot's hydraulics forces or indefinite instability constraint design opposing among response speed and overshoot control
Descending form	Might effortlessly escort to system consequence manage precision
Fuzzy	Difficult to adjust the fuzzy system. Overshoot prophecy instant not curved
Neural Network	Can't assemble the necessity of quick reaction multifaceted for real time application

2.1. UUV modelling under actuated condition

The thrusters are assembled in a design to provide the required drift to the vehicle. The open frame of the vehicle provides the best water flow, reducing the drag. Below actuated conditions is described as one having less control inputs than degree of freedom. Here some under actuated system, they require of actuation on definite guidelines or depth can be interpreted as constraints on the acceleration. For UUV, under actuated circumstance means when one or more of thrusters break down. The capability of to sustain a definite path or depth in its operation is address will be having two thrusters used for depth control. If one of thruster breaks down, the second thrusters will take over the control. The thrusters are having the 12 V to each.



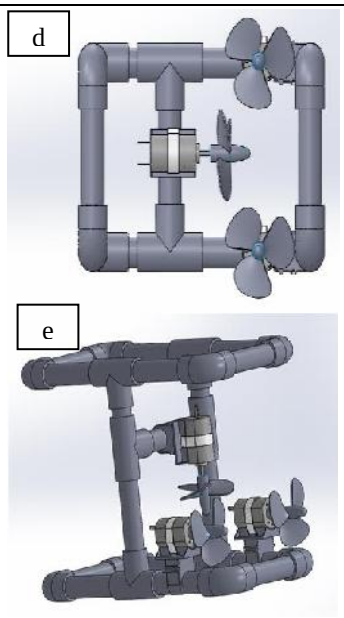


Fig.1. Thruster configuration (a) Top view of thruster (b) front view of thruster (c) Bottom view of thrusters (d) left view thruster (e) Right view of thrusters.

2.2. Master and Slave Controller Tether

The designed system is tethered through channel and remotely operates through an operative. Yoke material flanked by tether and wire design will be one of difficulty in solidity of system. Most of the systems entail a wire to convey the signal, video feedback, input voltage, and communication operator to the submerged vehicle. This will be attached stack to submerged Vehicle consignment, which are shown in figure 2. The vehicle dimension, mass, working deepness, motors (thruster), subsystem, power, signal, power essential and pick and place is the constraint is must regard as in scheming. Here are two common types instead of wire; one is the Umbilical cable and the second is tether cable. Normal ROV used an electromechanical cable.

Fig .2. Working of tethered UUV in testing tank.

This wire, in fact, will be achieved the mechanics and solidity of UUV. So how we can decrease the dimension of wire for UUV application. During function in submerged is energized through the battery within the UUV, although DC brushless motor and live video feedback were energized through battery which is place at the surface. Examination, Exploring and video feedback is essential part of technology.

2.3. Difficulties

The unmanned underwater vehicle robotic system is characterized by the need for working in a difficult underwater environment. Any such robot need to handle various problems to function efficiently and effectively, such as waterproofing of the equipment, Buoyancy of the vehicle in the water, Communication and controlling of the vehicle in the water and Navigation in different directions.

We have overcome these problems by balancing the vehicle by adding dummy weight to the vehicle to minimize the buoyancy problem. To prevail overcome the problem of waterproof equipments, we made a water-proof box in which the circuitry of vehicle is placed to prevent it from water. We eliminated the problem of controlling servo motor by increasing its voltage.

2.4. Controlling of UUV

The Play station 2 controller is a pleasant economical control interface by additional buttons and controls that are necessary for this project. Resembling the preceding editions of the ROV (remotely operated vehicle) control sketches, the PS2 controller is used for controlling equipment on the UUV such as the motors, motor direction, claw arm, and camera, as well as this prototype individual able to give the live video displayed on the topside station's LCD display.

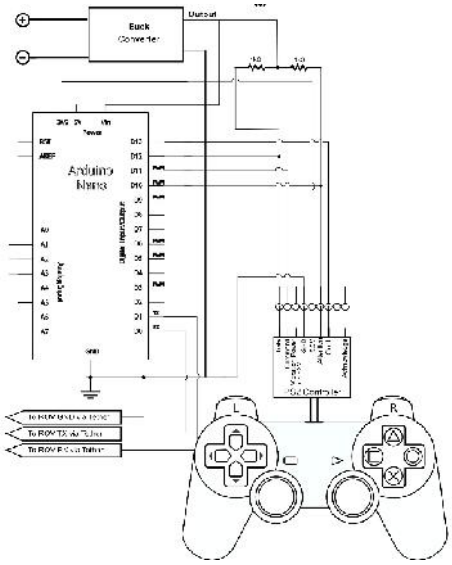


Fig. 3. Connection diagram of master controller.

Figure 3 shows the connection diagram of master controller.

In adding to the PS2 Controller, the topside station makes use of an Arduino Nano and a video LCD display. A buck converter is used to provide a 5V to the Command and Attention pins of the PS2 controller and 12 V to LCD display, the command pin of PS2 is connected to pin D11 of the Arduino pin GND is connect to GND pin 3.3v to 3v3, clock pin is connect to D13 of the Arduino respectively.

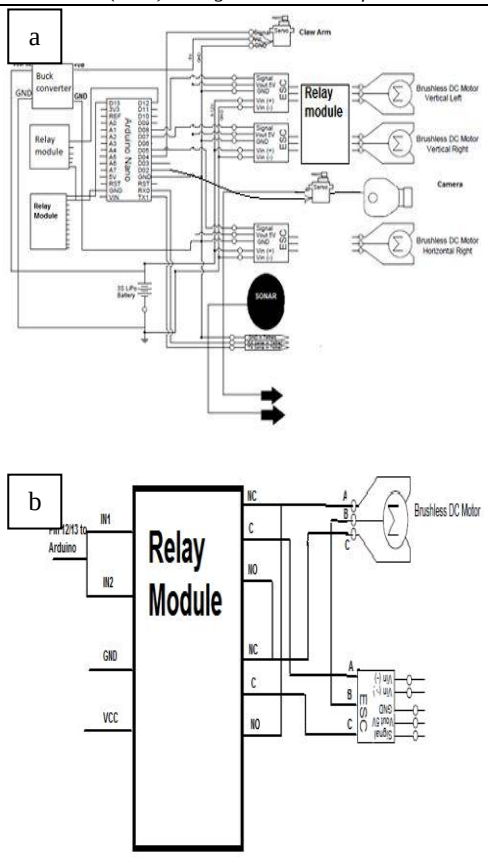


Fig.4.(a) Connection diagram of slave controller (b) connection diagram of thruster and relay module.

Fig. 4(a) shows the connection diagram of the salve controller and the connection of DC brushless motor also the connection of claw arm. The thrusters are connected to relay module, then the relay module is connected to the electronic speed controller (ESC). Fig. 4(b) shows the connection of thrusters and relay module.

The electronic circuit for the UUV is moderately uncomplicated because the majority of it is concerned with concerning fairly complicated equipment such as the speed controllers to the different pins on the Arduino. At this stage the board for the circuits is just paved collectively on Veroboard. formerly the circuit drawing as developed a appropriate circuit board will be developed.

2.5. Working Principle

Complete system operation is shown in system flow chart in Fig. 5 when user apply the instruction to the master controller through PS2 controller which are connected to the master controller and connection is shown in fig. 5, the system transmits the signal to the slave controller, with the salve controller the DC brushless motors are connected and servo motor of claw arm also connected. After receiving the signal from master controller, slave controller executes the function of the input signal which gives the feedback to the master controller. The input signal can be any which are defined already in programming that can perform the tasks like picking and placing the objects through claw arm, can also optimize the live feedback through camera and can also performs the task to move the vehicle in six directions.

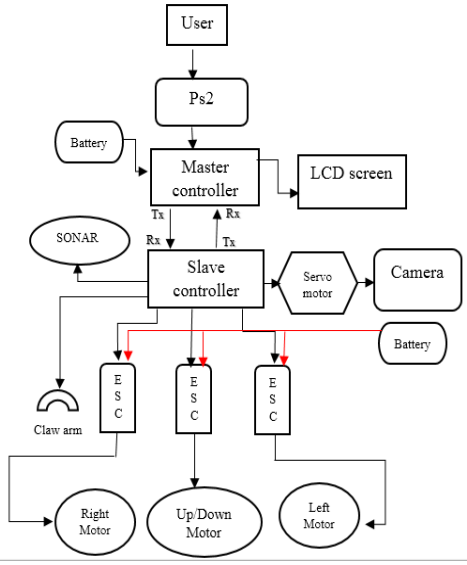


Fig. 5. Flow chart of UUV

3. Results and Discussion

Throughout the working on UUV towards the completion of final prototype, it has been observed that the behavior of UUV was as per requirement. The designed system worked accurately as per desired depth. The movement of claw arm which worked in direction of x-axis and camera, which moved in the direction of y-axis were accurate.it is used for underwater surveillance, inspection and for object recovery. It is the same as submarine but it has small size, low power consumption and low cost so it is more efficient. Initially the design system was not more efficient and functionally strong, which only works in four directions, there was no camera for live video feedback, no sonar for measuring its depth and no claw arm for picking and placing the objects. But in designed system is adding all these components which make it more efficient. The design vehicle is prototype model which performs all functions as described above. Fig. 6 shows the pulse width modulation (PWM) wave when we give the voltage to thrusters. The table II shows the characteristic of the prototype of Unmanned Underwater Vehicle (UUV).

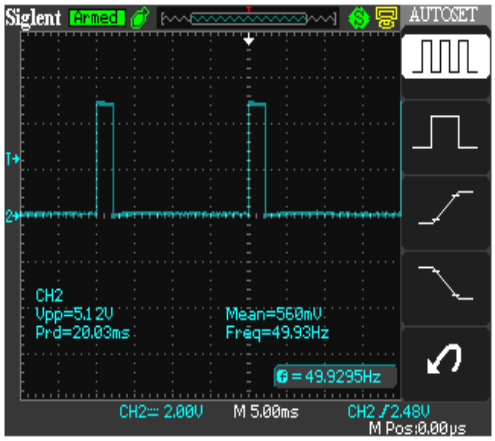


Fig.6. Shows the PWM of thrusters

TABLE II. Characteristics of UUV

Specifications	**Explanation**
Nominal speed	0.8km/h
Maximum speed	1.5km/h
Camera resolution	12 Mp, 1080p
Degree of freedom	3
Rated Voltage	12V
Operating Depth	5m

4. Conclusion

The final designed Unmanned Underwater Vehicle has been demonstrated to be performing well and the developed UUV is remotely operated through a joystick controller and is able to perform inspections and surveillance of underwater environment efficiently. The UUV is well designed; it is waterproof, protecting the relevant equipment and sensors from water. The main tasks that it can perform are: navigation in six directions; up, down, left, right, forward and backward, imaging and visual monitoring of environment through camera and performing basic pick and place tasks using the claw arm. However, the final designed and developed has some limitations; for example, it can work up to 5 meters depth and communication is through cables only. Its manipulability capabilities are limited and require further sensors to effectively monitor underwater environment.

5. Future Recommendation

Above mentioned limitations can be overcome by adding autonomous control system. The arm complexity will be increased, which is currently limited by platform payload capacity and increase the depth range, pressure sensor to determine the operating depth, temperature sensor, leakage sensor and infrared sensors for thermal imaging.

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Energy Harvesting for Water Quality Monitoring using Floating Sensor Networks: A Generic Framework

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Abstract:

Water is a constrained asset and basic requirement for animals, cultivation and industry that exist on this Earth including mankind. Subsequently, to measure the characteristics like physical, biological and chemical attributes of water becomes indispensable. Floating sensor networks (FSN) with in-situ sensors are now widely used to gather the water quality data. The main goal that deals with FSNs is data reliability, congestion control, optimal node placement and energy. So far, we proposed a generic framework for energy harvesting, reliable data transform congestion detection and deployment strategy for FSN to collect water quality data. Energy harvesting subsystem model will be designed to fulfil the needs for the desired application scenarios in sensor networks and extend the network lifetime. Therefore, this model will help in scheduling the sending/receiving, sleeping and idle time of the node. By incorporating this framework, network lifetime can be prolonged. For reliable data transform and congestion detection; a model will be developed to enhance the data delivery. The objectives of optimal node deployment are full coverage, network connectivity, improve the data fidelity and enhance the network lifetime.

Keywords: *Wireless sensor networks; Floating sensor network; Water quality; Energy harvesting; Reliable data transfer*.

1. Introduction

Water is the greatest blessing of Almighty Allah, so it plays a pivotal role for the survival of all living things. So, by keeping its importance we should understand its optimized usage. If we look around our surroundings, we can find that most of the people are unable to have good and hygienic water for drinking. Even most developed countries of the world are using filthy and polluted water for in taking deprived of suitably treated. This condition happens due to shortage of water quality monitoring and treatment systems. There are various sensors available for the monitoring of water parameters, like pH, oxygen density, temperature, humidity, salinity and so on [1]. Hence, for improving the water quality, its key parameters must be calculated before going towards quality sector. Water quality parameters, like temperature, conductivity,

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turbidity, salinity, pH, dissolved oxygen and total dissolved solids are the most important parameters of water to be measured. As, we know that the quality of water totally relies on these parameters. Once these parameters are calculated then it becomes much easier to work on water treatment procedures.

The hasty and prompt advancement of technology in the field of wireless sensor network (WSN) has capability of developing a novel tool for data acquisition, environmental monitoring, wireless back-end transmission and so on in terms of real-time deployment and implementation. Wireless sensor networks are composed of various tiny components called as nodes [2]. Each node consists of desired sensors, memory, processor, radio frequency (RF) transceiver, antenna, etc. The WSN field is a broad field in terms of types and application scenarios [3, 4]. Various types of wireless sensor networks are terrestrial WSNs, underwater WSNs, underground WSNs, floating WSNs; mobile WSNs. Wireless sensor network also seeks applications in water bodies by incorporating a new emerging field, so called as floating sensor networks (FSN) [5, 6]. Floating sensor networks with *in situ* sensors are now widely used to gain the water quality data. Floating sensor networks that take local measurements and water flows in water bodies and rivers are formally called as drifters [5-7].

So far, our focus is to propose a generic framework with reliable data transform and deployed in real time based on FSNs to monitor the water quality parameters powered by harvested energy. Many researchers have already worked on sensor networks-based water environmental monitoring with [8-10] and without [11-14] energy harvesting mechanisms [15-21] like, radio frequency (RF), solar, wind, thermal and flow. Meanwhile, different researcher in the state-of-the-art have focused on reliable data transform [22, 23] to enable the maximum data transmission and congestion control and optimal deployment strategies [24, 25] by addressing various deployment techniques such as, fixed, random, grid, hybrid and so on for sensor networks.

As for this proposed system, we will focus on measurement of parameters, such as temperature, conductivity, turbidity, salinity, pH, dissolved oxygen and total dissolved solids of water. For this, FSNs are excellent choice for monitoring different parameters and properties of water. The nodes will be equipped with these sensors and deployed into water bodies. These nodes will communicate via a wireless medium with sink node available at base station. For this task, various floating sensor nodes will be deployed fixed and randomly into water reservoirs. The nodes will be distributed for collecting the data and then transmit it via a prescribed wireless channel to base station and remote station for end user analysis. For continuous monitoring, energy harvesting mechanism will be provided. Solar and wind energy sources are incorporated to handle the power requirements. The harvested energy is stored in super capacitors and secondary batteries accordingly. To maintain the energy flow and ratings, an energy aware mechanism will be accorded. We also turn our focus on data transform by touching reliable data transfer and congestion control mechanisms and algorithms. A GUI tool will be designed for analyzing the results and statistics of water quality. There are two types of users for the analysis of water quality results, which are technical (experts and researcher) and non-technical people. For non-technical user, we will design a simple GUI tool for displaying the data.

1.1. Motivation

As Pakistan is populous country and it is facing huge water crises. So far, to overcome this issue we must take initially necessary steps for making water pure, for this; first the properties of water must be calculated to purify or improve its qualities. The water quality is an essential ingredient that plays a pivotal role for living organisms, their basic

needs and routine jobs, such as drinking, cooking, farming, etc. So far, this proposed system will be supportive to measure key parameters of water, which are necessary for the treatment of saline and soiled water. By measuring the key parameters, it will easily be arbitrated that whether this water is useful for drinking and irrigation or it would be treated. Hence, this proposed system will fulfil all these aspects and will be suitable to achieve this task.

1.2. Research Challenges

These research challenges will be faced during designing water quality monitoring system.

- FSNs are not suitable for continuous monitoring of water bodies/reservoirs, because they have limited life to measure the water parameters.
- The most significant challenge in the framework is interdependencies between the simulated scenarios and physical components of the system.
- There is no any sustainable energy mechanism for FSNs to collect continuous data.
- Energy harvesting subsystems are not easy to model in existing WSN simulators.
- Some realistic properties of the energy harvester are very challenging to implement in a simulator using a high-level programming.
- Design of complex algorithms for scheduling the different modes of the nodes like idle, sleep, sense, transmit, etc. to maximize the network lifetime and conserve more energy.
- Reliable data transfer in sensor network is a standout amongst the most essential issues.
- Significant resources are wasted when water quality data is missing, or instruments are not properly configured.

1.3. Contribution

Our contribution in this paper includes:

1) We have proposed a novel framework based on FSN for monitoring the water quality data.
2) In addition, we integrate energy harvesters into our framework for providing the continuous power supply. We also add super capacitors and batteries for storing the extra harvested energy. That can be used as a standby to cope the energy failure.
3) Next, we include a block for the reliable data transformation. This helps to maximize the data delivery ratio and curtails the packet loss ratio.
4) In last, an application is also suggested to get water quality data at remote or end users in terms of graphs and statistics.

In this study, paper organization is described as: section II covers the state-of-the-art. Problem statement is described in section III. In section IV, the research questions are addressed and the proposed generic framework for the system is described in section V. Section VI is all about the architecture of system and in addition, a novel architecture of FSN node to monitor the water quality data is also given. In section VII, the proposed methodology is illustrated. Expected outcomes in section VIII, Conclusion is given in section IX.

2. State of the Art

Here we discuss some existing work of different domain of research areas. In last, a comparative analysis is also given in TABLE I.

2.1. Floating Sensor Networks

A. Tinka, et al. (2013) [5] have presented a complete drifter system and acknowledged a pilot experiment in a controlled channel. The utility of the system for making

measurements in unknown environments is highlighted by a combined parameter estimation and data assimilation algorithm using an extended Kalman filter. These drifters were utilized to measure water quality data; DO, Temperature/Conductivity and pH.

D. Boydstun, et al. (2015) [7] have given the design, development and deployment of sensor network of drifter nodes. The target domain is coastal water monitoring and study of Lagrangian water dynamics. The nodes were equipped with a camera, inertial measurement unit (IMU), GPS, Wi-Fi and a computing unit. Each unit is water resistant with buoyancy characteristics that enable it to float in a vertical position.

2.2. Water Quality Monitoring

Yue and T. Ying, (2011) [8] have designed a WSN based system for water monitoring system and focused on measuring the oxygen content, turbidity and pH value of water. The system is powered via a solar cell. WSN nodes distrusted randomly and a sink node at base station for collecting the water quality data. The main advantage of this system is low power consumption and flexibility in deployment.

W. Y. Chung, and J. H. Yoo (2015) [9] have designed WSN based field servers to sense the information about water quality parameters from wide areas such as; coastal areas, rivers and streams. They have used solar energy harvester to energize the field servers. For the reduction of communication traffic and adequate data transmission in the middle of base station and field servers, they have designed a data averaging practice.

B. O'Flynn, et al. (2007) [11] have worked on measuring water quality parameters and WSN based multi sensor system design and titled as Smart Coast; a new platform has been designed and implemented for the investigation of water parameters for water quality management and measurement. Sensing devices of Smart Coast system were temperature, pH, oxygen content, conductivity, turbidity, and water level of water bodies.

D. S. Simbeye and S. F. Yang, (2014) [12] have designed real time wireless system for monitoring as well as controlling the various parameters of water. The parameters under monitoring and controlling were pH value, temperature, oxygen content, and water level. The sensed data transmitted via ZigBee transmitter to the base station. The Lab VIEW platform has been used for the analysis of outcomes.

2.3. Energy harvesting

F. K. Shaikh, and S. Zeadally (2016) [15] have presented a comprehensive review on the taxonomy of renewable energy sources towards wireless sensor networks and focused two classes of energy harvesting sources i.e., ambient sources and external sources. RF, solar, thermal and flow (wind and hydro) are lies under the category of ambient sources and mechanical (vibration, pressure and strain-stress) and humanoid (bodily, physical and activity) falls under the external energy harvesting sources.

A. Dewan, et al. (2014) [16] have reviewed about the renewable energy sources for powering the environmental monitoring systems located at remote areas. Their proposed system is a best alternative to the traditional batteries. Researchers initially discussed about remote sensors and then the power requirements and working principle of renewable sources for remote sensors, renewable energy sources challenges and finally, the power management.

2.3. Harvesting Techniques

J. J. E. Lopez, et al. (2018) [31] suggested that presently, batteries are generally used to power-up internet-of-things (IoT) devices. Though, use of batteries enforces significant restrictions to operation of system, because they require be recharging or interchanging after certain period of time. Depending on proposed application, this can be a very

challenging process or even not possible choice. To overcome these restrictions, designers are recurring to energy harvesting (EH) systems to extend battery life and allow independent operation of IoT end-nodes.

In current years, several power management units (PMUs) that harvest energy from single transducers have been introduced. The most common selected sources of energy are light, thermal gradients, mechanical vibrations and radio frequency (RF) signals. Though, it has been observed that due to ambient variations, single harvesting sources can exhibit long periods of energy shortage, which reduces their overall dependability. As main goal of a PMU is to provide a constant supply to its load, even when operating from irregular energy sources; design of an autonomous system that relies on single harvesting source can be quite challenging. Collecting energy from several sources turns to be more reliable method for powering IoT end-nodes. This is especially case if complementary / heterogeneous transducers are considered as harvesting devices.

2.4. Data Transformation

S. O. Olatinwo, and T. H. Joubert, (2018) [28] suggested that Wireless sensor network (WSN) technology is promising inexpensive method which involves deployment of different sensor nodes measuring water quality at a desired water-processing station. Monitoring parameters might normally include inorganic and organic contaminants such as pH detection, dissolved metal ion detection, and bacterial load detection. The data collected by water-quality sensor nodes concerning quality of water at water processing station is transmitted to different data centers. The data centers investigate water quality data, based on analysis and essential conclusions are made. WSN is not only valuable tool employed in water quality monitoring but also for water leakage monitoring, traffic monitoring, to collect, process, and distribute environmental data to several centers.

B. Ali, et al. (2018) [30] have proposed a reliable and energy-efficient routing (R-ERP2R) protocol for UWSNs water quality monitoring. This protocol balances energy consumption and decreases delay by utilizing physical distance at time of data packet transmission. Every sensor node calculates estimated transmission count for each of its neighbor to find link quality for reliable transmission of data packets. A lowest depth neighbor in range with high residual energy and good link quality is selected as forwarder. R-ERP2R forwards only one copy of a data packet to increase network lifetime. However, if a data Packet reaches void region, sensor node drops it which results in retransmissions.

2.5. WSN deployment for water quality monitoring

A. Goswami, and M. Kumar. (2017) [26] has presented concise review of protocols in WSN for energy harvesting. In Water Quality Monitoring: WSNs can be deployed under water or at surface to detect quality of water and create a more perfect map of Water status from all of above-mentioned sources. WSN reduces manual retrieval of data and inspires his team to help detecting places which are facing difficulties to access right quality of water.

M. Pule, et al. (2017) [27] viewed that Water quality monitoring has thus become important to supply of clean and safe water. Wireless sensor networks (WSN) have since been considered a promising alternate to complement conventional monitoring processes. These networks are relatively cheap and permit measurements to be taken remotely, in real-time and with negligible human interference.

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TABLE I. Comparative anlysis between proposed framework and existing frameowrks.

Sr. #	Compared parameters	Existing frameworks							
		[8]	*[9]*	*[10]*	*[11]*	*[12]*	*[29]*	*[31]*	*This work*
1.	Water quality sensors	✓	✓	✓	✓	✓	✓	×	✓
2.	Energy harvesting techniques	✓	✓	✓	×	×	×	✓	✓
3.	Energy management	✓	✓	×	✓	×	×	✓	✓
4.	Enrergy storage	✓	✓	✓	✓	×	✓	✓	✓
5.	IoT features	×	×	✓	×	✓	✓	✓	✓
6.	GPS Module	×	×	✓	×	×	×	×	✓
7.	GUI tool	✓	✓	✓	✓	×	×	×	✓
8.	Database / Memory	×	✓	✓	✓	✓	✓	×	✓
9.	End user application	×	×	✓	×	✓	✓	×	✓

3. Problem Statement

After the illustration of extensive literature review, it is concluded that the designed platforms and systems have not capability of continuous monitoring. Besides this, there is no any sustainable energy mechanism for FSNs to monitor the water quality data. FSNs are not suitable for continuous monitoring of water reservoirs. They have limited life to measure the water parameters. To overcome these issues, we have proposed to design a novel system in which there is no issue regarding power for operating the FSNs everlasting. The nodes should have capability of continuous monitoring of water bodies. Nodes should fetch the data autonomously.

The considerable problems of FSNs are energy management, reliable data dissemination, congestion detection, deployment strategy, security and management of a sensor network itself. The main problem is to simulate the network protocols in parallel with the environmental parameters, energy harvester, circuits and storage blocks. Also, it is an utmost issue for a node deployment strategy to meet the design objectives. Generally, the deployment of sensor nodes produces congestion in sensor networks. Lifetime evaluation of sensor networks is a challenging task, for which, these parameters require much consideration for the robustness:

- Energy harvesting and storage block
- Node scheduling
- Reliability and congestion control in the network
- Optimal node deployment
- Ad-hoc nature

4. Research Questions

Following are research questions of proposed work.

1) Is this course is limited to certain domain of water quality monitoring i.e. ocean, sea, streams, lakes, irrigation, drinking water, etc.?
2) Are we familiar about the parameters either natural/manmade that will affect the values of our concerned measuring parameters for water quality data?

3) The proposed system is strictly limited by means of computation, storage and communication. How can we handle and design such low complexity power management solutions for those hardware constraints?
4) Does the chosen energy harvesting subsystem model fulfil the needs of network lifetime of sensor node objectives for the desired applicative scenarios?
5) How can we organize duty cycle strategies to control congestion and ensure the reliability of data transmission?
6) What are the key factors that need to be considered for optimal placement of floating nodes at different deployment cases?

5. Generic Framework

The proposed generic framework consists of four different blocks as shown in Fig. 1. We must highlight these four blocks. (1) Application: FSN based [5-7] continuous monitoring of water parameters [8-14, 29] that will help for improving the water quality, (2) Energy harvesting [15-19]: provision of adequate energy for long life monitoring without replacing any battery, (3) Data transform [22, 23]: congestion control and reliable data transfer at remote station (4) Deployment [24, 25]: random deployment of floating nodes. The purpose of each block of the proposed framework is explained here.

5.1. Application

As we develop FSN based system for continuous water quality monitoring. Once the water quality parameters have been detected, then it becomes easier and simpler to improve its quality by incorporating different chemical procedures. Researchers may use this framework according to their desired application scenario like fish farms, habitat monitoring, bridge monitoring etc.

5.2. Energy harvesting

This block consists of two sub-blocks. First one is energy harvesters such as solar, wind, water flow, etc. For our prosed system, we are supposed to use solar and wind harvester as a renewable energy sources to fulfil the power needs of the proposed system devices like, sensing devices, microcontroller, communication devices, and so on. Second one is harvesting aware power Management. This block is concerned to handle, manage and storage of the harvested energy in super capacitor and secondary batteries and for providing useful energy as per their requirements.

5.3. Data transform

This block has two types of contributions the reliability module and congestion control. The purpose of reliability module is to transfer data reliably in terms of maximizing the data delivery ratio and minimizing the miss packets ratio. The contribution of congestion control block is to handle the packet transmissions without packet collisions, by incorporating different algorithms to minimize or avoid the number of re-transmissions in case of miss or dropped packet scenario. By which, packets collisions are sufficiently reduced.

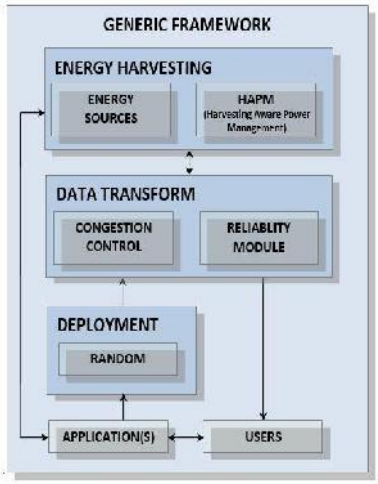


Fig. 1. Generic framework of proposed system

5.4. Deployment

The deployment of nodes can either be randomly or deterministically. It depends upon the requirement of the network or application designers. Well, we use fixed deployment or anchored deployment strategy and random deployment strategy for the proposed system. The pictorial representation of deployment strategies is given in Methodology section. The deployment strategies have a significant impact of the network metrics such as network topology, routing protocols, reliable data transfer and so on. So, for improving the network performance, we must adopt a suitable deployment strategy.

6. System Architecture

Fig. 2 depicts the energy process architecture: from harvesting to utilization and partitioned into three main sections as discussed below.

6.1. Energy harvesting sources: solar and wind

The energy harvesting sources consists of two distinct types of energy harvesters such as, solar and wind to fulfil the energy requirements. For improving the mission-life of FSNs, renewable energy sources will be provided accordingly. Energy harvester are used to facilitate the proposed system to avoid the abruptness and battery replacement in the measurement of water quality data. The harvested energy obtained from the harvesters is provided to different active electronic devices.

6.2. Energy-supply energy sources: super capacitors, batteries, converters and regulators

To provide desired voltage ranges as per specifications of devices, this practice is done via power management scheme by incorporating different energy converters and regulators such as MPPT. The maximum power point tracking (MPPT) [17] provides the maximum output efficiency by maintaining the duty cycles. Super capacitors and secondary batteries are here for storing the energy gained from energy harvesters [17-19].

6.3. Energy utilizers: processing devices, sensing devices and actives devices

This section is comprised of various active devices, which utilizes the energy viz. processing devices, sensing devices and their drive circuitries, communication devices, etc. According to datasheets, every device has different current and voltage ratings. So, for the provision of adequate energy as per device requirement is accomplished by energy converters and regulators as discussed as earlier.

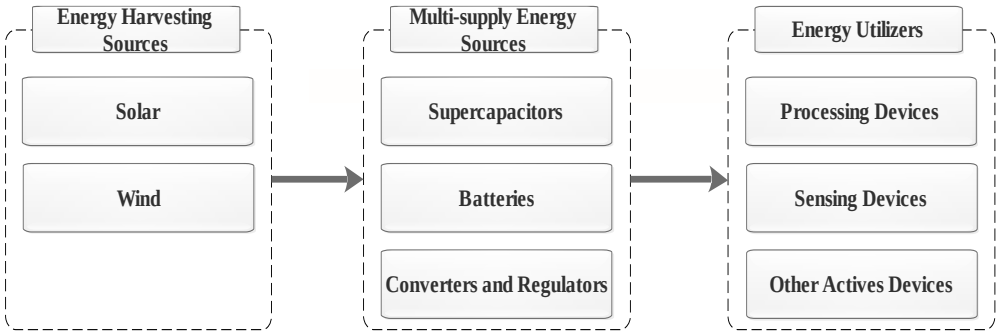


Fig. 2. Energy process architecture: from harvesting to utilization

Fig. 3 describes the black box general architecture of a novel FSN node for the proposed system, where different modules of the node are mentioned. The proposed

architecture of FSN node consists of sensing devices, microcontroller unit, ZigBee transceiver, GPS module and power management blocks (power source and energy buffers). Sensor node is composed of sensing devices along with drive circuitry and converts to enable the sensors for the communication with microcontroller unit. The fetched data is transmitted by ZigBee transceiver at the base station. GPS is used to track the position and location status of the nodes. To provide desired voltage ranges according to the specifications of devices; this practice is done via converters, MPPT controller and power management scheme.

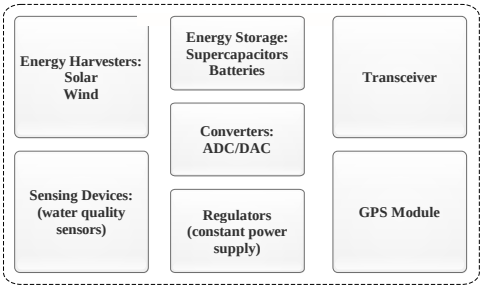


Fig. 3. FSN node general architecture

This FSN node has three different challenges, which are: shaping a new platform for real time monitoring efficiently, development of software algorithms to incorporate hardware for autonomous monitoring and data transferring, incorporation of various modules of the node with the microcontroller unit to achieve desire objectives by making it fully quantifiable.

7. Reseach Methodology

The deployment scenario of floating nodes is depicted in Fig. 4, in which fixed or anchored deployment is depicted in Fig. 4a and random deployment is depicted in Fig.. 4b for designing any novel platform for performing some dedicated tasks. The datasheet for each part of the system must be observed before selecting for proposed system. We are aimed to design a novel hardware platform for real time continuous monitoring of water quality parameters. There are various software platforms for the programing of the nodes. For the visualization of measured data, a GUI tool will be designed and database for record keeping. The proposed system is comprised of a sink node at base station and various number of sensor nodes deployed in water bodies. ZigBee transceiver is responsible for transferring the data to base station. The GPS module will be equipped with sensor nodes for tracking the position and location status. The nodes will be deployed randomly into water reservoirs for real time monitoring and continuously.

Our proposed methodology is based on following five steps:

7.1. Data collection

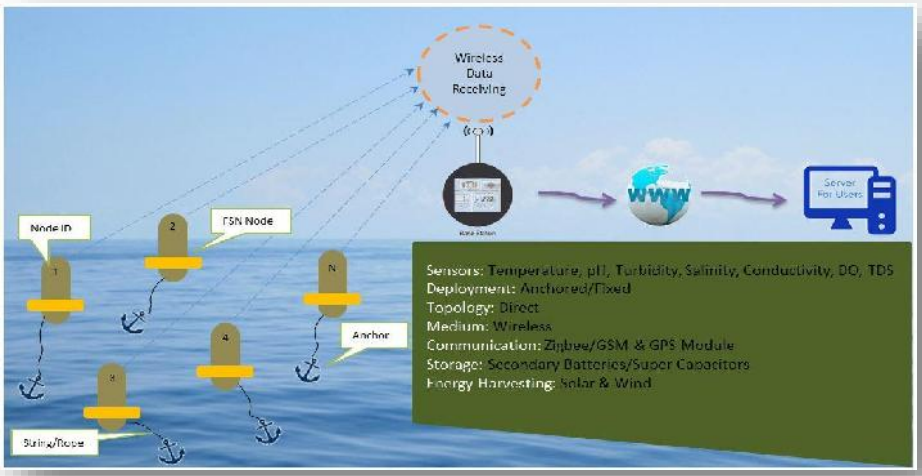
In the first step of proposed system of the network various floating nodes will be deployed in the water (lake or river). Each node will be equipped with different sensors which are temperature, conductivity, turbidity, salinity, pH, dissolved oxygen and total dissolved solids. These nodes will be designed and programmed to collect water parameters individually and that sensed data after collection is stored in the microcontroller accordingly.

7.2. Data transmission

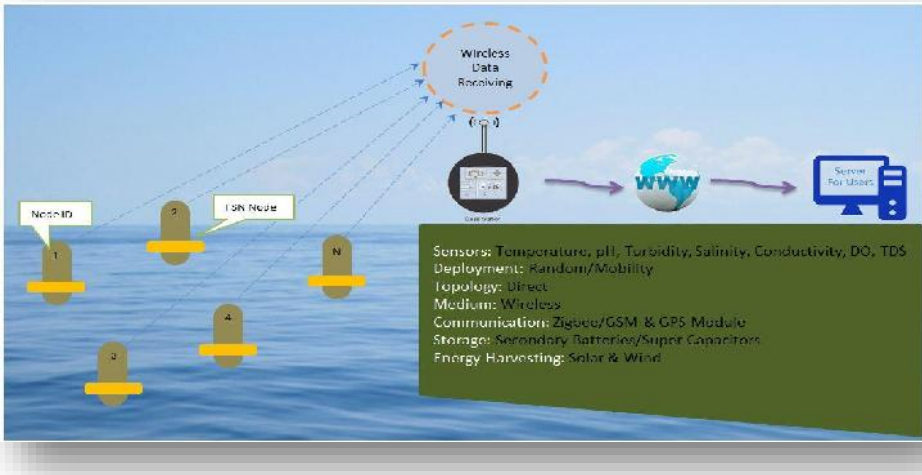
In the second step, the data will be transmitted wireless, and ZigBee transceiver module will be used at transmission and reception sides. All nodes will send the collected data to central monitoring center or base station using direct topology. The position of each node is also accorded at base station via GPS module for updating the status of locations.

7.3. Base station

In the third step, base station will collect the data from all floating nodes using ZigBee transceiver, where visualization of data via GUI tool will be carried out. After receiving data from each node, the data is sent to the Ethernet shield which is used as a gateway to transfer the data over web for end user.



(a) Anchored/Fixed Deployment



(b) Random Deployment

Fig. 4. Proposed Research Methodology

7.4. www

In the fourth step the data will be sent over the web, by which the data is accessed by the server for further processing. Also, end user can access the data via internet sources.

7.5. Server

In the last step the data will be received at server via internet and stored in the database for further processing, initially the data will be differentiated using the node IDs to process the data of each node separately, after

identification the data is collected by web for final step, over here three tasks will be executed which are given below.

- *Status check:* this is used to check the status of each node whether it is up or down, sometimes the transmission is interrupted because of higher attenuation causing object in between or temporary failure of link etc.
- *Graphs generation:* here, the data of each sensor is used to generate a continuous line graphs to show the instantaneous values and status of the water relating to the sensor.

Notifications/Alerts: Notifications and alerts will be used to indicate if any of the water parameter is not in the desired state and has crossed threshold, it will be notified by triggering warning to use precautions to make the parameters back to normal

8. Expected Outcomes

The proposed energy harvesting based FSN system is beneficial for both public and private sectors. The proposed novel system tackles two most key issues; energy and water that are being faced in our country Pakistan very dramatically. Furthermore, we have evaporated some other pivotal role of our system under following sections.

8.1. Industry

There are various water-purifiers, food factories, raw material (cement, etc.) factories and industries are available around the world, for these procedures, safe water is an important ingredient. For the provision of safe and hygienic water, water quality monitoring system will play pivotal role for the treatment of water. This proposed system is fit for this requirement.

8.2. Academia

Academia is the main part of research in this world and day by day it is promoted exhaustively by fetching and executing the ideas that are developed by the researchers. By working on this project, we can develop the linkages of useful research among the researchers and can produce different creative domains of research for further enhancement and improvement in the water quality monitoring domain.

8.3. Community

As water is the fundamental need of human beings and other living organisms. According to medical research, a common human being is using average of 10 liters of water every day for their survival on this Earth and obviously being a sensible human, we cannot tolerate the quality factor of this basic need. Hence, by monitoring the parameters of water we can improve the quality of water at its best, so that, every living organism can access or avail good quality water.

8.4. Government

After successful compilation of the statistics of water quality data, government can invest to develop some water purification plants to provide the best quality water to industries, communities, and other sectors of environment around us.

9. Conclusion

The proposed work has provided the details regarding the experience picked up in the context of development of a system of floating sensor network for collecting water quality data by introducing a novel framework. The proposed framework comprised of four domains; 1) application (e.g., water quality monitoring system), 2) energy harvesting, 3) data transform and 4) deployment. Meanwhile, each block also classified into sub-classes. We have addressed to propose a system based on FSN to monitor the water quality data continuously. For which we have introduced a novel architecture for FSN node platform.

The FSN Node is equipped with in-situ sensors; The FSN collect the data and transmit it at the base station via ZigBee transceiver module. Where measured data is displayed on

a display tool for users and a database for record keeping. As well as, this data is transmitted at remote station for end users via internet.

For the accomplishment of continuing monitoring, the alternating energy sources such as solar wind is provided to FSNs. The data transform module is addressed for the improvement of data reliability of the proposed system and avoid the congestion created during the data transmission. The proposed methodology of FSNs node deployment are addressed to be fixed deployment and random deployment at different outdoor sites for continuous monitoring. Finally, we have highlighted the end users and beneficiaries for which this proposed system is useful for the water treatment procedures.

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Electric Field Distribution In Transformer Bushing

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Abstract

The bushings are insulating devices of the power system they allow electrical conductors to pass current and resist the flow of current to the conducting tanks in case of transformers and circuit breakers. These bushings are typically made of porcelain material. The bushing must be designed to withstand electrical as well as mechanical stresses. The electric field stresses may develops the leakage paths within the insulation and if these stresses increased beyond the dielectric strength of insulation, it may puncture the bushing insulation and will allow the electric current to pass through earthed material causing burning and arcing. Mostly the electric field is not uniformly across the bushing therefore, a simulation is carried out to analyze and calculate the characteristics of electric field distribution In this paper, a transformer porcelain solid type bushing with oil as cooling and dielectric material is used. The Finite Element Analysis (FEM) technique is used to calculate electric field distribution along the solid type bushing transformer. It is projected that the results will provide an improved understanding of the EF distribution on the bushing outlet. This study may also assist in scheming HV bushing which can reduce the magnitude EF in the bushing.

Keywords: *Bushing, Electric Field (EF) distribution, Finite Element Analysis (FEA).*

1. Introduction

HV bushing insulators are used to provide weather proof protection for the exposed ends of transformer. A bushing consists of a hollow insulating line from which HV conductor passes through an earthed wall, such as the metal tank that encloses an oil insulated transformer. The bushing insulates the HV conductor from earth and also provides a means of mechanically supporting the conductor. The bushings connect the transformer windings, supply line and insulate the feeder via conductor from the main tank of the transformer. According to the electrical and physical observation, bushing is the feeblest part of the transformer. Besides HV bushing is the connection between outer and inner insulating schemes. The HV is fed into the transformer vessel and has to endure high loads, the electric field strength, mechanical forces, chemical loads and contaminations because of environmental and thermal pollution. For this reason, the bushings plays significant role in the operation of HV equipment [1].

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The reliability of bushing is crucial for the operation of the transformer. Bushings mechanically support external conductors and provide insulation from earth as the conductors are fed into the transformer tank. Moreover, bushings are one of the important elements of transformers and it was found to be the most common reasons of disastrous breakdown of transformers and nearby protective devices [2].

The transformers are one of the most intentional and expensive equipment of electrical power system. It was found from past literature that almost 25 to 30% of transformer breakdown are due to the bushing failure [3-5]. Since transformer bushings have no moving parts, most failures are attributed to insulation deterioration from moisture ingress [6] and electrical discharges. The bushing represents only a small fraction of the power transformer cost but their failure is often catastrophic. Failures do not only damage the transformer but can often cause significant damage to equipment in the proximity and consequently causes significant disruption. The study of the EF distribution along outer surface of the bushing is of key importance as it is used to evaluate the potential initiation of partial discharges. The reliability of bushing is crucial for the operation of the transformer. Bushings mechanically support external conductors and provide insulation from earth as the conductors are fed into the transformer tank [4].

The majority of bushings in the real practice are as old as the transformers. So monitoring the bushing condition and its maintenance is necessary. All HV bushings should be examined frequently every 3-5 years. During inspection if deterioration sign is found then bushing should be examined every 6 months and detached from service if the tests display a hazardous condition [2]. The commencement of bushing failure is not easily detectable at the initial stage that could later lead to an unwanted failure of the bushing, even though breakdown of the transformer. Insulation breakdown is one of the severe failures of transformers which can produce extensive financial losses of the utility. Consequently, utilities are recommended to continually check the conditions of transformers to avoid unwanted power outage and decrease failure rate. However, the formation of voids and air bubbles during modeling, installation and operation of insulating equipments is the main cause of insulator flashover and deterioration of power equipments. The presence of voids and air bubbles inside the dielectric material has lesser value of permittivity than the surrounding insulating material and higher electric field stresses that could lead to formation of weak spots in the insulation.

In power transformer, the oil-paper insulation has been extensively incorporated in the designing of bushing structures due to its decent heat transfer and electrical properties. Though, lengthy experience to severe electrical, mechanical and thermal stresses can weaken the oil vital possessions and split the paper insulation bonds resulting in the production of water, carbon dioxide, carbon monoxide. Partial discharge (PD) activity can be generated if air bubbles are found in the insulation and can carbonize the material (insulation) forming conducting paths which can ultimately short out bushing layers. The lack of mechanical and thermal stresses could also be the cause of lack of continuity of the conducting bushings and arcing [2]. Therefore, transformer bushings have been designed in such a way that reduces field stresses at transformer insulation.

2. Mathematical Formulation

The distribution of EF is obtained using the electric potential (EP) equation. The basic principal field equations of the model are.

$$\vec{\nabla} \bullet \vec{D} = \rho_f \qquad (1)$$

$$\frac{\partial \rho_f}{\partial t} + \overrightarrow{J_f} \bullet \vec{\nabla} = 0 \qquad (2)$$

Where equation 1 and 2 shows the field model and current continuity equations respectively. J_f , ρ_f and D are the free current density, charge density and the electric displacement field respectively.

3. Model Description

The '2D axial symmetry' model was built in COMSOL Multi-physics; the 'Quasi-static electric' is selected under the 'AC /DC module' to solve the EF distribution. Figure 1 shows a transformer bushing model and its dimensions and components. To model the distribution of EF along surface of the bushing (outer), the model is enclosed by air. The boundary conditions for transformer bushing model geometries are given in Table I and the associated material properties used to set the sub domains are given in Table II. Figure 2 and 3 shows the 2D axial-symmetric model geometry, the mesh elements and the boundaries for calculation of electric field distributions.

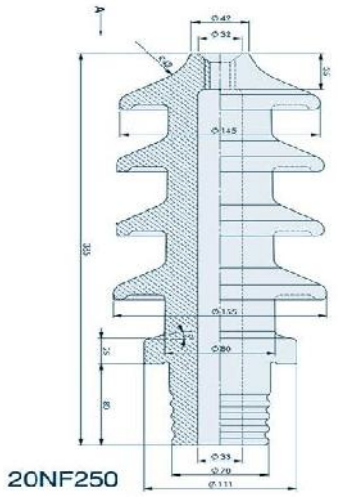
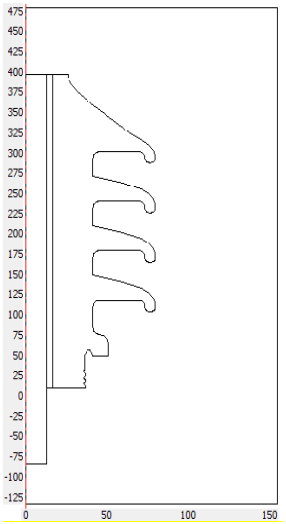
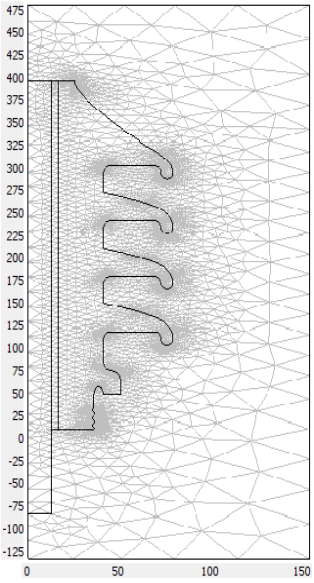


Fig. 1. 2D transformer bushing model [7].



(a)



(b)

Fig. 2. 2D axial-symmetric transformer bushing (a) model geometry and (b) with meshing.

TABLE I. Model boundary conditions

Boundary line	***Boundary condition***	***Description***
Green and black line	Electric Potential	Conductor boundaries
Red dotted line	Axial Symmetry	Boundaries along r=0 line
Pink line	Floating Potential	Outer surface of the cap
Blue line	Continuity	Bushing interior boundaries

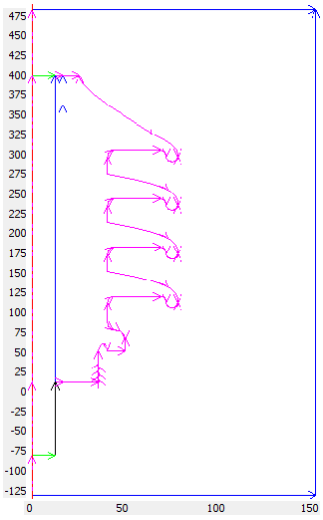


Fig.3. Bushing model geometry with boundaries.

TABLE II. Sub-domain settings in model geometry.

Material	***Permittivity ε_r***
Air	1
Porcelain cap	6
Aluminium	1
Oil	2.3

4. Simulation Results

The simulation of EF distribution in the developed model is shown in Figure 4. The entire structure length is 385 mm, diameter of conductor and bushing (plate) is 12 mm and the 155mm respectively. The applied voltage is 11 kV, the magnitude of maximum EF is observed at the cap of porcelain as this part of the cap has floating potential boundary. The maximum EF is found to be 805.887 V/m at the porcelain cap (edge) region. The oil as the insulation material of the conductor reduces the EF magnitude around the conductor region.

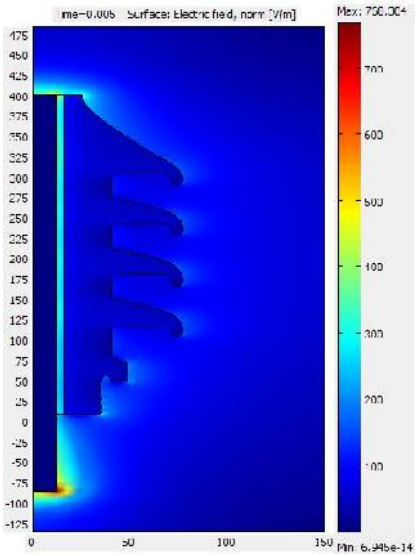


Fig. 4. Simulated electric field distribution in transformer bushing.

Figure 5 shows the plot of magnitude of the EF in the developed model. It has been found that the magnitude of the EF is not uniform and is because of materials having different permittivity value in the structure and boundary condition. For the developed model, the electric field is zero after r = 0 m because of the conductor region. The next region after the conductor consists of the insulation material. The magnitude of EF is at peak at the nearest area to the conductor and drops within the insulation material at the site

far away from the conductor. After the first and second insulation layer as shown in Figure 5, the magnitude of electric field is nearly identical within the bushing region made of the porcelain insulation material. There is discontinuous electric field between the insulation material porcelain and the air layer next to it, because the air permittivity is different.

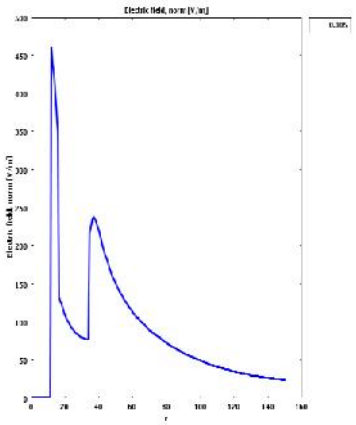


Fig. 5. Cross-sectional view of electric field in the bushing model

Figure 6 shows the magnitude of EF at a definite point in the insulation material subjected to the material permittivity for the developed model. It has been found in the developed model that the magnitude of electric field decreases when material permittivity is higher.

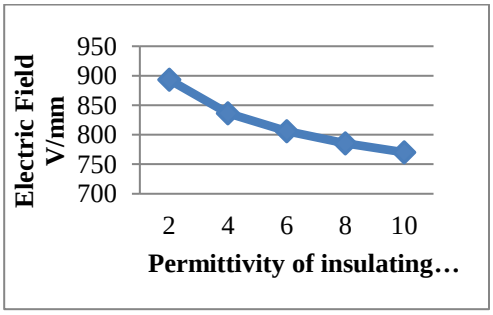


Fig. 6. Relation between the electric field and permittivity of the insulating material.

The permittivity defines the capability of the insulation material to align the EF. Therefore, a higher permittivity of the insulation means that the aptitude of the insulation to align the EF is better, resulting in less EF attentiveness in the insulation material. For Figures 6, the magnitude of EF in the bushing subjected to the permittivity of the insulation material.

5. Conclusion

The two dimensional axial symmetry model of transformer bushing was made through the Finite Element Analysis (FEA) technique. The simulation was done to examine the distribution of EF in transformer bushing. The effect of the bushing permittivity has also been studied. From the simulation results, it was found that the high EF is mainly concentrated at the edge of aluminum cap and bushing plate. It was also concluded that the magnitude of EF in the bushing is inversely proportional to the permittivity HV bushing material.

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A Comprehensive Study on Reactive and Proactive Routing Protocols under different performance Metric

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Abstract

Mobile Ad-hoc Network (MANET) has recently gained enormous studies attention because of their large potential of reliability and scalability in various fields. Besides, this Ad-hoc network is very flexible in nature which makes it more valuable for the researcher in the research area. Ad-hoc network provides better mobility due to which it uses dynamic topology. The routing protocols possess a very important role in any MANET. The routing protocols are divided into three big categories reactive protocols (on demand), proactive protocols (table-driven) and hybrid. The different routing protocols were created, which perform differently under different scenarios. This survey paper investigates the reactive and proactive routing protocol performance under different scenarios. The routing protocols like AODV, DSR, DSDV, AODV Modified (R-AODV) and TORA are compared under different parameters. The NS2 simulation tool is used for the simulation purpose. This paper shows the previous work done by the researchers in the field of reactive and proactive routing protocol based on its comparative analysis. Our results, contrarily to previously reported studies conducted on the same routing protocols, show the superiority of reactive over proactive protocols in routing such traffic under different network scenarios and parameters.

Keywords: *AODV, DSR, DSDV, TORA, R-AODV*

1. Introduction

A Lot of work has been done in the area of routing protocols in recent time. Many routing protocols have been proposed for Ad-hoc community with attention on optimizing distinct aspects of the network routing. The Wireless Ad-hoc network is the collection of a group of mobile computers. The nodes help in packet forwarding and allow communication beyond its transmission range. A wireless Ad-Hoc network community is a decentralized form of wireless network which does no longer rely on a pre-existing infrastructure. As wireless Ad-hoc network does not require a central device or control management. Therefore, it is easy to establish when needed. The routers in the network are free movers in any direction. Therefore, the topology is dynamic in nature. Every node in the wireless ad-hoc network may act both as an end consumer node or a router and could, therefore, trade its Link to different nodes often. It also enables other nodes to determine a path to another cell node and perform packet delivery that might not in the direct wireless communication. Ad-hoc provides flexible and big advantages in different environment such as military, commercial and technology. The interest of the researchers is increased for the Ad-hoc networks for a distributed set of applications. Applications such as gaming, military applications, commercial application and

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crises management services applications [1, 2].

As there is no specific device in this environment, therefore, the security challenges are the great concern for the researchers to work on it. Many demanding situations that still need to be solved in such regions as addressing, routing, place control, configuration management, interoperability, security, and excessive capacity technologies [3, 4]. The routing is the procedure which is used to choose a path in a network. The main function of routing protocol is the selection of routes for multiple source destinations and its accurate delivery to the destination. In Ad-hoc networking the mobile nodes are used for searching the route or paths for the connection and sharing the data. The performance of any routing protocol is the end to end delay, throughput, PDF, NRL and Route Acquisition Time etc.

2. Routing Protocols

The Ad-hoc routing protocols are classified into three big classes

2.1. Table-driven (proactive Algorithms)

This Algorithm simply uses the tables. The data are stored and updated in these tables.
Examples are (DSDV), (WRP) wireless routing protocol (GSR) global state routing [4, 5].

2.2. On Demand (reactive Algorithms)

This Algorithm creates routes on demand bases by flooding the network with Route Request packets. The two key procedures of source initiated on demand-driven routing protocols are the route discovery process and route maintenance process. ABR, AODV, and DSR are reactive routing protocols.

2.3. Hybrid protocols

The composite of table driven and on-demand routing protocols which possess the attributes of both routing protocols together. ZRP, CEDAR, and LAR routing protocols belongs to hybrid protocols [6].

In section 3 the protocols that are used in Ad-hoc are discussed. Section 4 describes comparison evaluation of routing protocols. Section 5 describes the simulation result of protocols. The last section presents the result and conclusion.

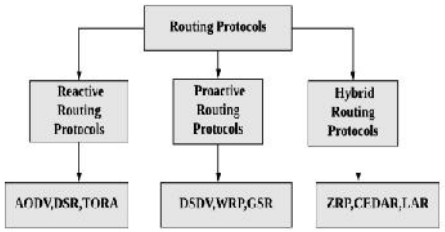

Fig 1. Different classes of routing protocols

3. An Overview Of Protocols

3.1. Ad-hoc on-demand vector protocol (AODV)

AODV is on demand protocol which creates the route on demand. The nodes move here and there very quickly which results in breaking links. The message mechanisms are having RREQs, RREPs, and RERRs. Route Maintenance and route discovery are used by AODV Whenever a sender wants to create a route its route discovery process can be done through flooding route request message. All the neighbors include in this process as they all get the route request messages. After reaching the destination route reply packet sends back on the same path used by RREQ packet. Each node maintains a sequence number and a routing table. The loop-free operation takes place in AODV which helps in repairing of breakage links. Whenever a link breaks, the affected nodes are informed about the infected or lost link [7, 8, 9, and 10].

3.2. Dynamic Source Routing Protocol (DSR)

This protocol is designed for the multi-hop networks of moving nodes. This is an efficient routing protocol which is based on demand routing protocol which has a self-organizing network. Working of this protocol can be illustrated in two steps Route identification and route Management. DSR guarantee loop-free routing. The source node will first check the route of the node in a cache to which it wants to send a packet. If it tries to find the route, it sends the packet. Otherwise it uses route discovery. After the destination received the packet, it stores the information contained by RREQs and sends a reply back to a source node. The route mechanism is responsible for checking whether the topology changes or not. In case of breakage of a link, that route is removed from cache route and informs all nodes by sending RERRs [12, 13, and 14].

3.3. Destination- sequenced distance vector Protocol (DSDV)

DSDV is a table-driven based on Bellman-ford scheme. C. Perkins and P.Bhagwat developed DSDV in 1994. This algorithm helps in removing the routing loop problem. The records are recorded in a table. Every node entered in a table contains a sequence number. When the connection exists the series number is even else an odd number is used. The routing records sent between nodes with smaller updates usually.

Every node advertises routing information using broadcasting a routing table packet updated in case of network topology changes. Loop-Free and count to infinity problem is much reduced in DSDV [12, 13, and 14].

3.4. Modified Ad-hoc on-demand vector protocol (R-AODV)

It is the new version of AODV routing protocol with some modification in AODV. The R-AODV tries to manufacture a more dependable way between the source and destination keeping route stability under consideration. The change has been done in Hello and RREQ messages. In R-AODV new field is embedded by Hello message to record the sending time. At whatever point the (i+1)th node gets HELLO message sent from the ith node, it should record the HELLO messages arrival postpone time d_time. In route discovery stage the (i+1) th node gathers the d_time values of hello message reached within the predefined period and makes count to these. At last, the (i+1)th node appends them to the RREQ packet and surges/floods the bundles to the neighbors. At the point when the RREQ packet achieves the goal, the goal can choose a steady and solid route to the source as indicated by these measurements [17, 18].

3.5. Temporally Ordered Routing Algorithm (TORA)

It is an on-demand routing protocol which works on the concept of path reversal of the directed A-cyclic Graph (DAG). TORA searches multiple routes from sender to destination. TORA is a loop-free and bandwidth efficient protocol that's why TORA has the property to repair the route quickly during link breakage and provides multiple paths for the desired destination. It works well in networks where traffic increases gradually. TORA operate in the dynamic network. It uses Parameter "Height" to greatly emphasize the direction of a path between the nodes. TORA supports multicasting. TORA can be used in conjunction with Lightweight Adaptive Multicast Algorithm (LAM) to provide multicasting. The disadvantage of TORA is that the algorithm may also produce temporary invalid routes as in LMR.

Information in a network is managed in three different ways.

i. Route Erasure
ii. Route Discovery
iii. Route Maintenance

The protocol is able to detect the partition and erase all invalid routes [19, 20].

4. Survey Of Routing Protocols Performance Evaluation

The following performance metrics are used for performance investigation of protocols.

4.1. Throughput

To check the total rate of transmitted packets in a unit time in the network. The nodes received by the receiver per unit time.

$$Throughput = \frac{(pr \times psize)}{1000} \quad [3]$$

pr is used for the packet received and *psize* is the size of packets in bits.

4.2. Average End -to- End delay

The average time used by the sender to send the packets to the receiver. All the possible delays are included in it.

$$Average\ Delay = \frac{Total\ delay}{Count} \ [3]$$

i = packet sequence number
count = Total packet count
delay[i] = receiving_time[i] – sending_time[i]
Total_Delay = Total Delay + delay[i]

4.3. NRL

The total number of packets transmitted per data packet delivered at the destination.

$$NRL = \frac{pc}{pd} \quad [3]$$

Where *pc* is the total control packets and the *pd* is the total number of packets sent.

4.4. PDR

PDR is the ratio of a successful amount of data delivered to the destination sends by the source. PDR is used to measure the efficiency of protocols

$$PDR = \frac{pr}{ps} \times 100 \ [3]$$

pr is used for a packet received and *ps* is used for a packet sent.

5. Literature Review On Protocols

5.1. Throughput

In the case of low mobility the throughput of AODV is higher than comparatively to DSR and DSDV. AODV gives better throughput than R-AODV. The DSDV performance is not very strong in a high mobility within the constant value 10 to 30 percent. The performance of TORA is better at high mobility but it has a lower throughput in other cases [1, 2, 3, 4, 5].

5.2. Packet Delivery Ratio (PDR)

The packet delivery for DSR is the best among the protocols. The DSR is best in terms of Average PDR. AODV is having low PDR than DSR because it drops a higher number of packets. Packet loss of AODV is less than DSDV. DSDV performs worst for packet delivery. The packet loss issue is very sensitive in TORA compared to other routing protocols. TORA packet delivery is less than AODV. The PDR for Modified-AODV is the same as AODV but changes in velocity decrease rapidly in case of AODV. [1, 2, 3, 4, 5, 19, 20].

5.3. End-to-End delay

The Delay of AODV and DSR is more than DSDV. The routes are not shortest due to which AODV and DSR delay is poor. The TORA protocol is also having worst delay characteristics because of the loss of distance information with progress. The average delay of R-AODV is less than AODV

5.4. Normalized Routing Load (NRL)

The NRL for AODV is highest among the other routing protocols. DSDV has the least NRL which shows that DSDV is the best routing protocol for the optimal shortest path.

6. Simulation Results And Analysis

This section explains the simulation analysis carried out for the routing protocols. According to the different author's papers, the simulation results for the routing protocols are discussed below.

6.1. PDR (Packet delivery ratio)

A Wajid Khan [3] the result of PDR analysis for routing protocol describes that DSR works better under small network. DSR is greater than AODV. In the medium and larger network size, AODV works efficiently. Its PDR is greater. The reason behind it is that as the route discovery process is very quick, it allows the AODV to adapt to the route changes quickly.

Ajay Prakash [2] results show that while increasing pause time the PDF of AODV and DSDV is continuously decreasing for 10 numbers of a node. The results also describe that PDF of AODV is larger than DSDV.

Sapna S [5] according to their simulation result as the load will be less for less number of nodes DSR performs well. DSR performance slightly decreases as the number of nodes increased. DSDV performs better than the other two protocols with nodes increased. AODV also performs better but as nodes increase its performance slow down.

Anuj k [19] simulation result shows TORA is quite sensitive to packet loss than other protocols. The PDF of AODV is slightly less than DSR.

Humaira Nishat [18] papers compared the AODV and R-AODV. The result shows that the PDR for both the protocols is the same but with the increase of velocity, AODV ratio decreases. Whereas R-AODV remains the same.

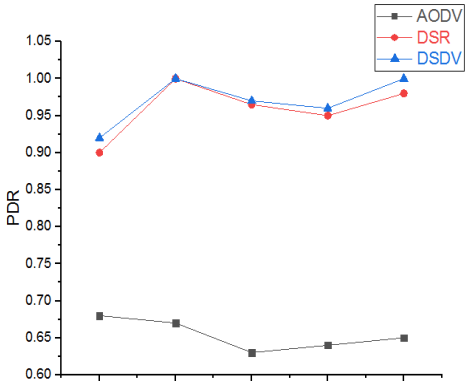

Fig 2: Packet delivery Ratio of AODV, DSDV, DSR

This graph shows the comparison of AODV, DSR, and DSDV under the PDR parameter. It shows that AODV performance is better as the packet delivery ratio is less than the other two protocols. The other two protocols packet delivery ratio is high.

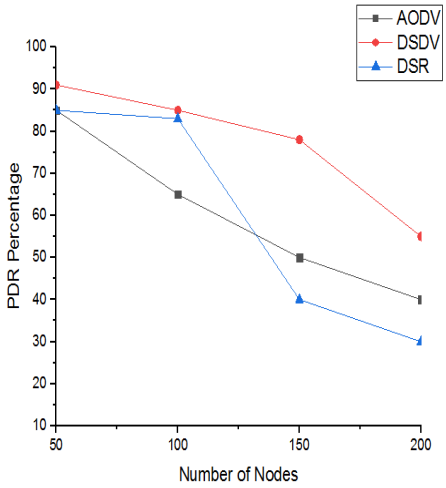

Fig 3: PDR of AODV, DSR, and DSDV

In this graph 200 numbers of nodes are used for the comparison of AODV, DSR, and DSDV. The protocols were compared under different network sizes such as small, medium and large. DSR works better under small network size while for the large and medium size network AOD performs better.

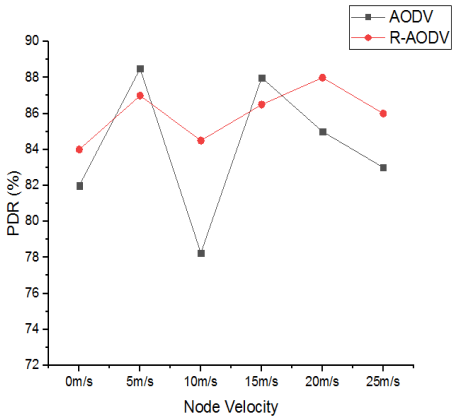

Fig 4: PDR of AODV and R-AODV

The graph shows that with the increase in node velocity AODV ratio decreases. The overall performance of both the protocols was the same.

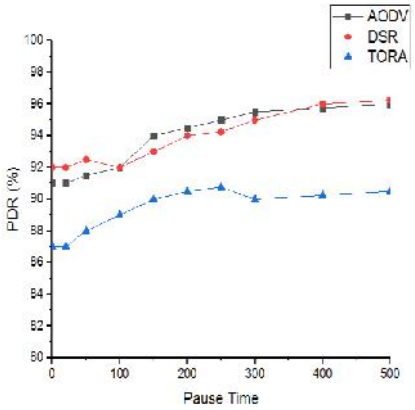

Fig 5: PDR of AODV, DSR, and TORA

The graph shows that AODV has lower PDR than DSR because of a high rate of packet dropping

6.2. Throughput

According to the paper of A Wajid khan [3], the throughput parameter is checked for AODV, DSR and DSDV routing protocols under different network scenarios like small, medium and large. The results show that the AODV protocol received more packets than the other two protocols. DSR throughput is not good in all networks. The reason behind the low performance is linked breakage.

Akshai Aggarwal [4] paper result shows that AODV performance is better under a large number of nodes, while DSR performance is better for a small number of nodes.

V. Rajeshkumar [9] this paper focuses on the comparison of three routing protocols such as AODV, DSR, and DSDV. The no of nodes was (30, 40, and 50). The overall performance of AODV was higher than the other two protocols. As AODV is loop-free therefore the routing packets for it is much more. DSR performs slightly low than AODV. Anuj k [19] paper describes that the overall performance of AODV is better. TORA performs well for high mobility rate while for low mobility its performance was low.

Humaira Nishat [18] the performance of both protocols was the same for the throughput but as the speed increases behind 18m/s R-AODV performance becomes low.

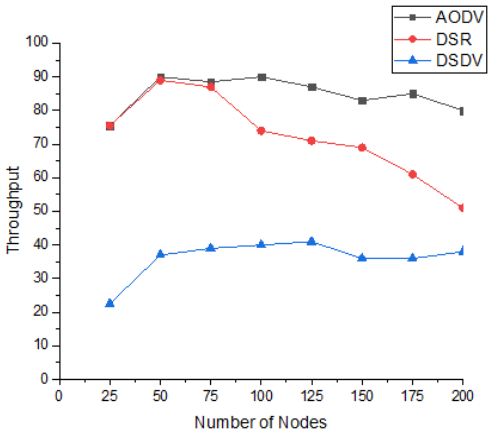

Fig 6:-Throughput for AODV, DSR, and DSDV

This graph represents the performance of protocols for the throughput parameter. According to this graph result, the throughput of AODV is high than other protocols.

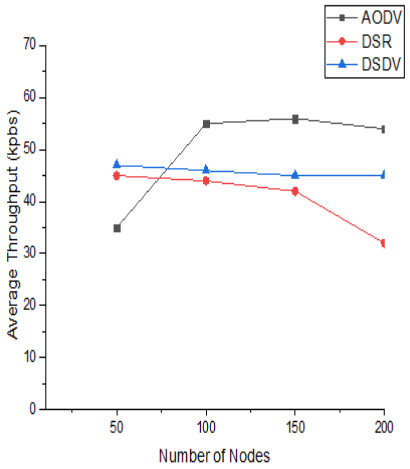

Fig 7: Average Throughput of AODV, DSR, and DSDV

The graph shows that AODV throughput is higher than DSR and DSDV

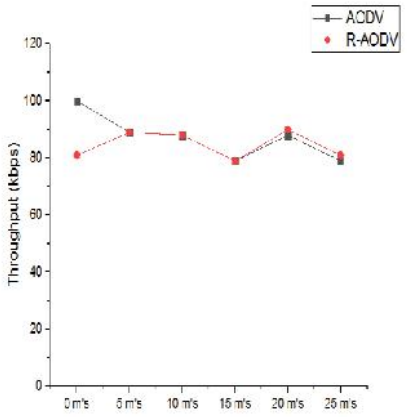

Fig 8*:* A throughput of AODV and R-AODV

The result of the graph shows that as the speed increases R-AODV performance becomes low. Both protocols result is almost the same.

6.3. End-To-End Delay

A Wajid khan [3] the average end to end delay of DSR is better than AODV. The AODV has very high delay under all network conditions. Ajay Prakash [2] the graphs show that the delay of AODV is much higher than DSDV. The reason behind the end to end delay is as AODV contains the address of next hop. During link breakage, the route discovery process Re-initiate which is waste of time.

Anuj k [19] the author compared AODV, DSR and TORA protocols. According to his simulation, the end to end delay was very poor for both AODV and DSR. DSR delay was slightly higher than AODV. The end to end delay decreases as the pause time increases. Similarly, TORA performance was also not very good. The reconstruction of a route was also not very quick which results in lengthy delays.

Humaira Nishat [18] the average delay of R-AODV is less than AODV. AODV gives more delay than R-AODV.

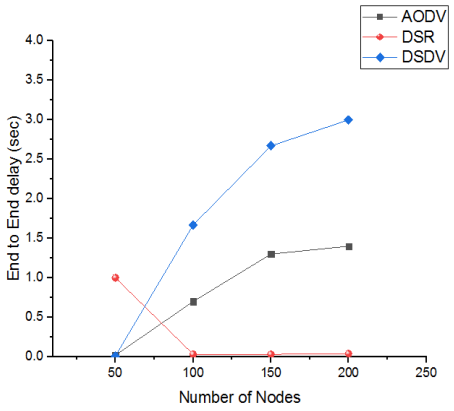

Fig 9: End to End Delay of AODV, DSR, and DSDV (with 10 connections)

The graph indicates the comparison of three protocols namely AODV, DSR, and DSDV. According to the result of the graph, the result of DSR is better than the other protocol.

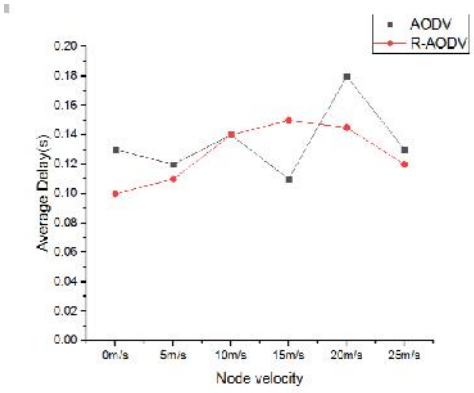

Fig 10: End to End delay of AODV and R-AODV

This graph compares the result for the AODV and R-AODV. The result of both the protocol shows that R-AODV performs better for the end to end delay

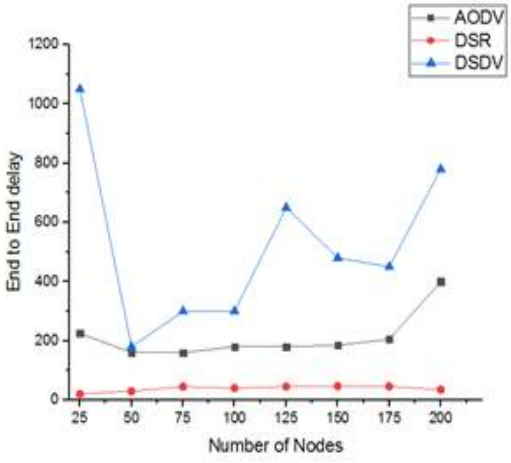

Fig 11*:* End to End delay of AODV, DSR and DSDV

The result of the graph shows that the average end to end delay of DSR is better than AODV and DSDV

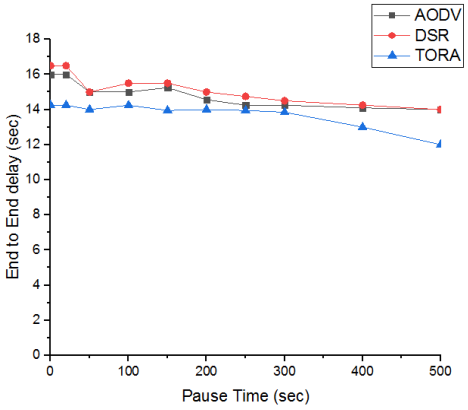

Fig 12: End to End Delay AODV, DSR and TORA

This comparative analysis is based on the protocols such as AODV, DSR, and TORA for the parameters end to end delay. According to the result, TORA performs better than AODV and DSR.

6.4. NRL (Normalized routing load)

A Wajid khan [3] the authors analyzed the performance of routing protocols for NRL. The result **shows** that AODV has low NRL in small and medium networks than DSR in a large network. Amirhossein Moravejosharieh[21] According to the author the DSR protocol has the best NRL than other protocols. In the value of density, DSDV has highest NRL while in speed density M-AODV has highest NRL. Guntupalli Lakshmikanth [22] according to their simulation result the NRL is 15 times increased in AODV and DSDV as the number of nodes increased from 40 to 100. The DSR increased 25 %.

Geetha Jayakumar [23] According to the simulation result it shows that with the different variation of pause time DSR performs better than AODV. The NRL was low of DSR than AODV. AODV route discovery process takes more time than DSR. Therefore DSR has low NRL than AODV.

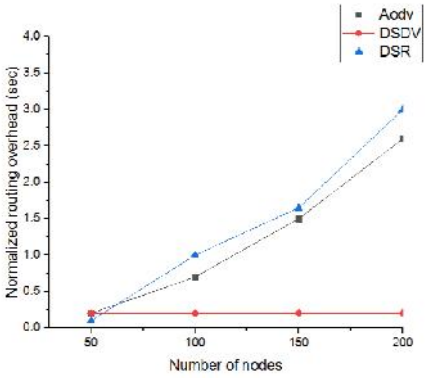

Fig 13: NRL of AODV, DSR, DSDV

This graph represents the performance of protocols for NRL which show that for both small and medium AODV has low NRL, while DSR performs better for large size.

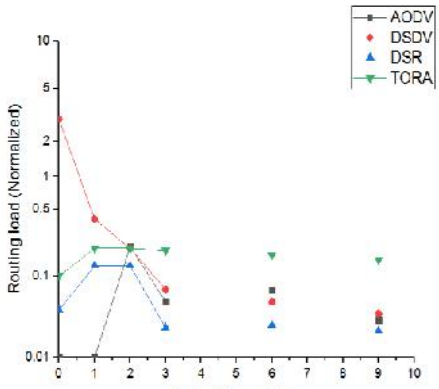

Fig 14:-NRL of AODV, DSDV, DSR, and TORA under low mobility case

This graph is based on the performance analysis of AODV, DSR, DSDV, and TORA which indicates that the DSR performs better than the other protocols.

TABLE I. Comparative Analysis of Routing Protocols

PROTOCOL PROPERTY	Avg AODV	Avg DSR	Avg DSDV	Avg TORA
Paper/Author Name	Anuj k [19]	Anuj k[19]	Anuj k[19]	Anuj k[19]
Throughput	N/A	N/A	N/A	N/A
PDR	95 %	95.5 %	N/A	90 %
End to End Delay	16 sec	17 sec	N/A	14.25 sec
Paper/Author Name	Samir Robert[24]	Samir Robert [24]	Samir Robert [24]	Samir Robert [24]
NRL	0.3 sec	0.1sec	3 sec	0.3 sec

The table indicates the average result for the following routing protocols under different parameters. The results are based upon the paper of A Wajid khan [3]. The total number of nodes used in the simulation process is (50,100,150,200).

The simulation time is 100 sec. packet size is 512 and interval time is 0.1. The overall performance of AODV is better for all Parameters

TABLE II. Comparative Analysis of AODV and R-AODV

PROTOCOL PROPERTY	Avg AODV	Avg R-AODV
Paper/Author Name	Humaira Nishat [18]	Humaira Nishat [18]
Throughput	100 %	81 %
PDR	88 %	86 %
End to End Delay	0.18 sec	0.14 sec
NRL	N/A	N/A

This table is based on the paper of Humaira Nishat [18]. The comparison has been done for two protocols AODV and R-AODV. The mobile nodes are 25 with the packet size of 1500B. The performance of both the protocols is same but with the changes in the network scenarios R-AODV performs low.

TABLE III. Comparative analysis of Routing Protocols

PROTOCOL PROPERTY	Avg AODV	Avg DSR	Avg DSDV
Paper/Author Name	A Wajid khan [3]	A Wajid khan [3]	A Wajid khan [3]
Throughput	55 %	45 %	45%
PDR	85 %	91 %	86 %
End to End Delay	1.5 sec	3.0 sec	0. 2 sec
NRL	2.65 sec	3.0 sec	0. 2 sec

The table indicates the result of reactive and proactive routing protocols for different parameters. The results were taken from two papers such as Anuj k [19] and Samir Robert [24]. The simulation parameters used in Anuj k [19] are as following. The simulation time was 200 sec with the area of 500.500. CBR (UDP) traffic type was used. 500 nodes are used.

Samir Robert [24] the number of nodes used is 10. This result is for low mobility network. The packet size used is 512.

7. Result and Conclusion

In this survey paper, a comprehensive analysis of reactive and proactive routing protocols under different performance metrics has been done. The different work of the author is also discussed on the bases of the simulation. All routing protocols show good result under specific performance metrics. The average results are shown with the help of graphs and tables of each routing protocols which explains the performance of the reactive and proactive routing protocols in detail.

After comparing all the reactive and proactive routing protocols under different parameters, the overall performance of AODV routing protocol is better than the other protocols.

In the case of throughput, the AODV receives more packets than the other protocols. The NRL of AODV is also lowerssss than the other protocols in different network scenarios. End to end delay and packet delivery ratio (PDR) is also medium in AODV than the other protocols.

8. Future Work

To analyze and compare the combination of protocols such as R-AODV and TORA with the other reactive and proactive routing protocols with the different parameters under the network sizes such as small, medium and large. The following parameters such as Throughput, NRL, Jitter, Latency and collision should keep under consideration while comparing the routing protocols.

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A Smart On-grid Solar Charge Controller

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Abstract:

The theme of this project is to design a hybrid system which harnesses electricity from renewable source that is the sun using photo-voltaic solar panels as long as the Sun is available to charge batteries and operate load and when it is not available For example at night or in cloudy weather or in the rain the charging of batteries is switched from sun to the other alternative source such as UPS (Uninterrupted Power Supply) or through AC source.AC source of 220V in the project is given through AC source. This project focuses on utilization of renewable source of energy.

Ofcourse the energy from sun varies along the day which varies the energy generated from it. So to protect our batteries from being overcharged or fully-discharged we have designed a charge controller which determines the battery's SOC (State of Charge) and determines whether to charge it from solar or the alternative source if provide by us. This hybrid system aims to keep our batteries often running and that in the healthy condition [1].

1. Introduction

The untenable nature of fossil fuels and its appalling effect onto environment create concerns for an environmental friendly alternative energy source as fossil fuel dependence increases exponentially. Fossil-fuels are motive for greenhouse emissions, incompetent use of energy and deliverance of harmful contaminant to the atmosphere we realized usage of renewable energy sources concerning the safety of our environment. Due to expensive prices and declining of fossil fuel, we are introducing Charging mechanism for solar powered vehicle. Also, solar energy is clean and green source among all renewable sources because it provides 3.8 x 10^{26} Joules/day**,** low maintenance cost**,** also researcher focus on new techniques with innovative ideas on solar energy that's why its efficiency Improves day by day, if we review today's market solar energy is fastest alternative for standalone system. We are implementing this technology because of its improvement in efficiency, growth and effectiveness. Application Area of our project that it can be used as hybrid charging of battery. We can use charge controller as grid connected especially it is best for villagers where there is load shedding of about 20/24h, one cannot survive without electricity, that's why we have proposed a charge controller which is charged by using national grid supply as well as solar.

Our charge controller charges the battery with 20A and 24V whenever voltages of solar reduced below the 20V automatically WAPDA supply charges the battery by triggering relay 2 and our PWM

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charge controller prevents the battery from overcharging. Over Discharging and reverse power flow, and charge our battery smoothly hence the life time of battery is increased and continue to supply our loads [2].

2. Charge Controller

As the output of solar is varying and fluctuated because the energy and direction of sun is always changing at every second or due to bad weather, the electrical desired values for battery charging are not achieved. So we need here charge controller which also prevents battery from over-charging, over discharging and reverse battery control [3].

Functions of charge controller

Functions of charge controller are defined below.

- Prevention from Overcharging: transistors are used to limit the Amperes if battery is charged.
- Prevention from Over Discharging**:** cut-off the supply if voltage of battery falls down threshold level.
- Blockage from Reverse Charging**:** Diode are used as reverse bias for prevention of reverse voltages towards solar side.
- Control-Functions**:** timer is used to control the load connection and disconnections.

3. Types of Charge Controller

There are basically two types of charge controller PWM & MPPT**,** now a days these two methods are mostly used in Off-Grid system, the decision to use any of the above has not depend on power output, but it depends on the design of system and as well as weather conditions. If we want to differentiate between these two controllers, Power curves is best. It shows the power generation based on potential difference and current [4].

PWM Charge controller

PWM activates when battery is almost fully charged. When the controller supplies voltage to battery until panel voltages equals to battery voltage and there is direct connection between panel and battery. When the battery and panel voltages are equals, controller disconnects the PV and battery, and battery voltage is constant this fast-connecting method is called as shown in figure 1.

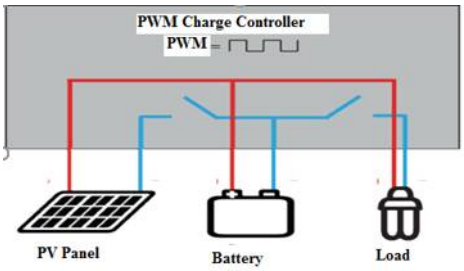

Fig 1: PWM charge controller

Battery is protected by overcharging, it works slightly above the maximum power point of solar panels as shown in figure 2.

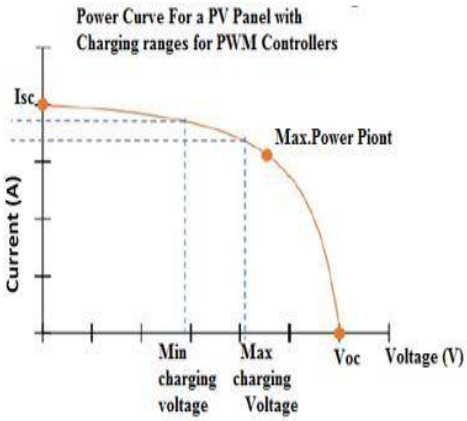

Fig 2: Power curve for PWM controller

MPPT Charge Controller

This controller has unintended link between solar panels and battery, unintended link consists of DC-DC converter that actually gets Solar voltage and converts it into current and reducing voltages where Power is not affected, Block diagram is shown in figure 3.

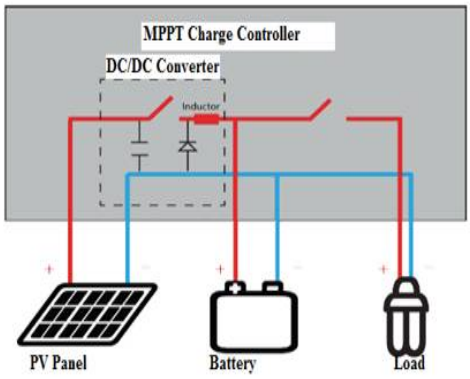

Fig 3: MPPT charge controller

The power curve for maximum power transfer is shown in figure 4 below.

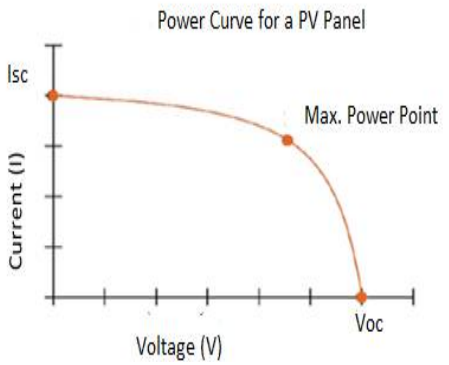

Fig 4: Power curve for PWM charge controller

Difference between both controllers

We are going to select a suitable charge controller on the basis of cost, efficiency, complexity, availability. That is why we understand the difference between charge controllers in below Table I.

Table I: Difference between both controllers

PWM	MPPT
Cost efficient almost half of MPPT	Expensive
Longer lifespan because of complex circuit	Lifespan is less because of electronic circuit
Less thermal stress	High thermal stress
Smaller Size	Bulky Size
Used for 150-200W power system	Used above 200W design
PV array sized on voltage basis	PV array is sized on basis of power

Two way on-grid solar charge controller

Charge controllers are designed to control the device voltage and open the circuit, halting the charging when the battery voltage is supposed to reach a certain level. Most of the charge controller uses mechanical relays to make or break the circuit of device and battery. The charge controller that we have designed is on the method, which continuously monitors the battery voltage, and based on that monitoring it charges the battery through solar panel voltages. It is also known as hybrid charge controller because it keeps on charging the battery even when solar panel voltages reaches below a certain limit. That is done through main 220V WAPDA source. During day time when solar panel voltage goes above 20V the controller switches to charging of battery through solar sources, and during night or due to unconditional weather when solar panel voltage goes below 20V, the controller switches to main WAPDA source for the charging of battery.

4. Experiment

Our experiment goes through four stages.

- Solar panel
- Charge controller
- Batteries
- Load

Solar Panel

Solar PV cells consist of silicon or particular types of semiconductor materials which converts the solar energy into DC electricity. Batteries are required to store energy for use in emergency and night time. A PV or solar energy system, is consisted of solar cells. These cells are connected in series and parallel to provide required current and voltage which in turns forms PV module. Likely these modules are connected in parallel and in series making a network of modules to produce the desired current and voltage. However, the PV output current and voltage is dependent on ambient temperature and irradiance hence (I-V) characteristics of PV module changed nonlinearly in accordance with change in irradiance and temperature. Commonly, there is a special point on the current-voltage I-V or power-voltage P-V curve of a photovoltaic array where the output power of module has maximum value. In order to get maximum power from the array, it must be operated constantly at this maximum power factor (MPP). Due to the nature of the photovoltaic system, the maximum output power varies with the variation in solar radiation and climate conditions, mainly the temperature. The position of the MPP on the I-V curve of the module is not always acknowledge, so it needs to be decided either through calculation methods or with the help of any search method and algorithm [6].

PV module is modelled in MATLAB SIMULINK by modelling standard equations and equations are given below.

$$I = I_{ph} - I_D - I_{sh} \quad (1)$$

$$I_D = I_s [\exp (V_D/V_T) - 1] \quad (2)$$

$$I_{sh} = \frac{V + IRs}{Rsh} \quad (3)$$

$$I_{ph} = [\, I_{sh} + K_{SC} * (T_C - T_O) * (\frac{G}{Gs}) \,] \quad (4)$$

Now module current equation become

$$I = I_{ph} - I_s [\exp (V_D/V_T) - 1] - \frac{V + IRs}{Rsh} \quad (5)$$

All these equations were modeled in SIMULINK and resultant model will become as show in figure 5.

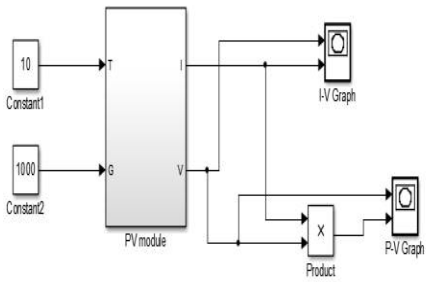

Fig 5: Presentation of whole PV module

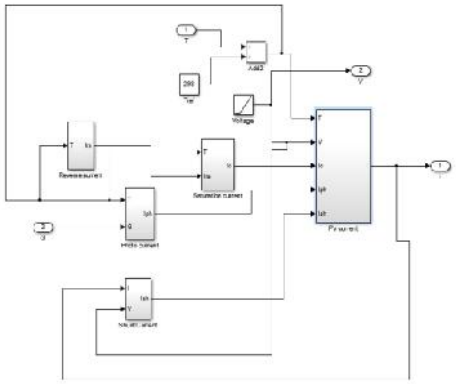

Fig 6: Grouped Subsystem of PV module

Analysis of PV Model

The model has been run under different ambient condition by changing temperature and irradiance as the input to the model to observe the I-V and P-V characteristics of

the panel. When we vary the temperature, the irradiance is kept constant and vice versa. The module data used is shown in Table II.

Table II: Module Data

Solar module SM55		
Electrical parameters		
Maximum power rating P_{max}	[Wp] [1]	55
Rated current I_{MPP}	[A]	3.15
Rated voltage V_{MPP}	[V]	17.4
Short circuit current I_{SC}	[A]	3.45
Open circuit voltage V_{OC}	[V]	21.7
Thermal parameters		
NOCT [2]	[°C]	45 ±2
Temp. coefficient: short-circuit current		1.2mA / °C
Temp. coefficient: open-circuit voltage		-0.7 V / °C
Qualification test parameters [4]		
Temperature cycling range	[°C]	-40 to +85
Humidity freeze, Damp heat	[%RH]	85
Maximum permitted system voltage [V]		600 (nach VDE 0126)
Wind Loading PSF	[N/m²]	50 [2400]
Maximum distortion [3]	[°]	1.2
Hailstone impact Inches	[mm]	1.0 [25]
MPH	[m/s]	52 [v=23]
Weight Pounds	[kg]	12 [5.6]

Effect of Variation of Irradiance

Here as the irradiance increases, short circuit current also increases along with the open circuit voltage. Because of both increasing of V and I, the P_{max} also increases according the irradiance. I-V characteristics under varying irradiance are shown in Figure 7 and 8.

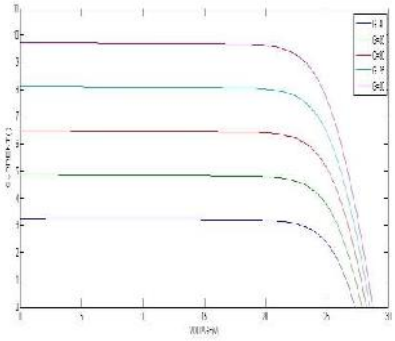

Fig 7: I-V characteristics under varying irradiance

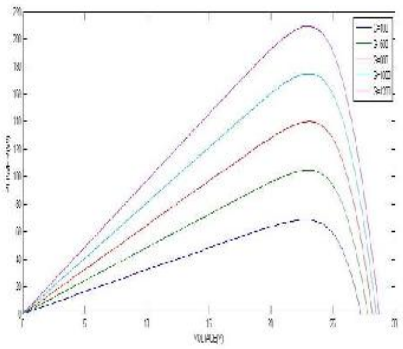

Fig 8: P-V characteristics under varying irradiance

Effect of Variation of Temperature

The simulation is run under the condition of variable temperature and constant irradiance. The open circuit voltage falls as temperature increases, but the short circuit current is less in high temperature. The maximum power point is also inversely proportional to the temperature. I-V characteristics under varying temperature are shown in Figure 9 and 10.

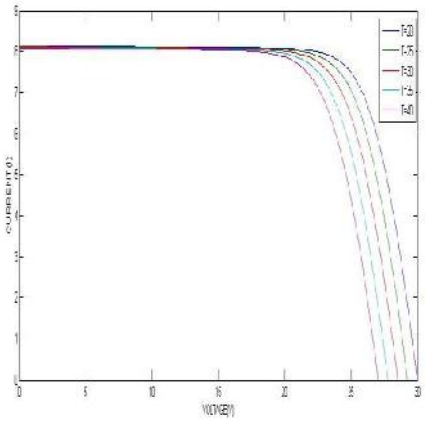

Fig 9: I-V characteristics under varying temperature

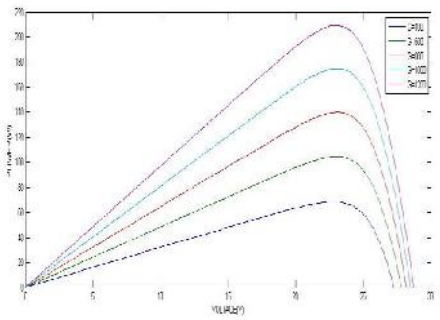

Fig 10: P-V characteristics under varying temperature

Charge Controller

Charge controllers are designed to control the device voltage and open the circuit, halting the charging when the battery voltage is supposed to reach a certain level. Most of the charge controller uses mechanical relays to make or break the circuit of device and battery. The charge controller that we have designed is on the method, which continuously monitors the battery voltage, and based on that monitoring it charges the battery through solar panel voltages. It is also known as hybrid charge controller because it keeps on charging the battery even when solar panel voltages reaches below a certain limit. That is done through main 220V WAPDA source, During day time when solar panel voltage goes above 20V the controller switches to charging of battery through solar sources, and during night or due to unconditional weather when solar panel voltage goes below 20V the controller switches to main WAPDA source for the charging of battery.

Batteries

The main theme of the Battery is to convert chemical energy to electrical energy and vice versa. It is two terminal devices: a positive (Anode) and negative (cathode), voltage difference depends upon the chemical reaction of the electrolyte, this battery may be used to store the charges or used as Power supply for the loads. We used lead acid battery in our project due to its prominent feature ad advantages [7].

Lead acid Battery

In this battery, chemical reaction takes place between Electrolyte of H_2SO_4 and H_2O, this is earliest battery, a separator is used between these two electrolytes.

When load is connected to this battery, Sulphate ions are bonded with sheet and sulphuric acid discharge from battery as shown in shown as Figure 11.

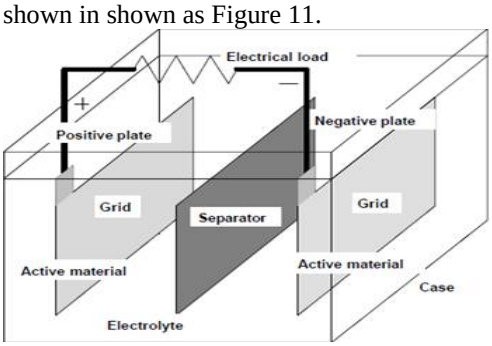

Fig 11: Lead Acid Battery

Load

For testing LOAD we used two 12V DC Fans connected with the battery as shown in Figure 12.

Fig 12: DC Fans (as a loads)

5. Results

We are taking the results of hardware step-by-step first connecting whole setup, all the results will display on the LCD and LCD provides us user friendly information.

Fig 13: Connection of Battery with System is displayed

In order to charge batteries, we connect our batteries with charge controller, and when batteries will be connected the LCD will display the capacity of system i-e 24V and 20A. If required voltage is being supplied from panels, charge controller will start to charge the batteries as shown in Figure 14. In case weather is much cloudy or it is night time, then controller will switch to alternative 20V supply and continue to charge batteries as shown in Figure 15.

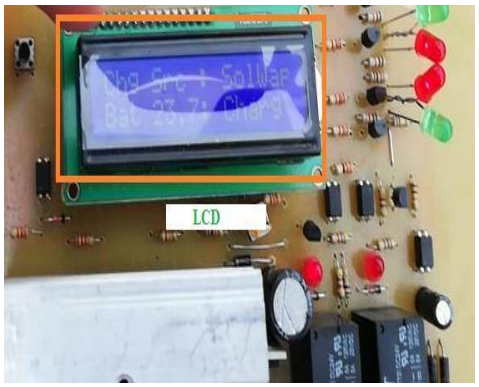

Fig 14: Batteries Charges from Solar

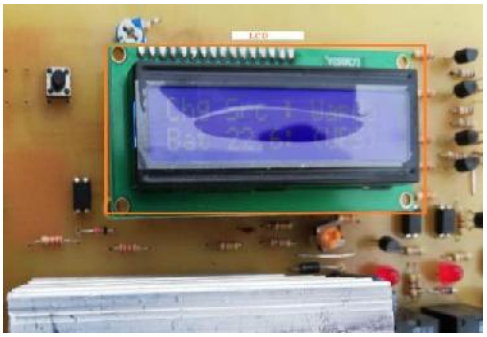

Fig 15: Charging of Battery through AC source

Figure 16 shows the whole circuit of solar charge controller which is being designed in this work of research.

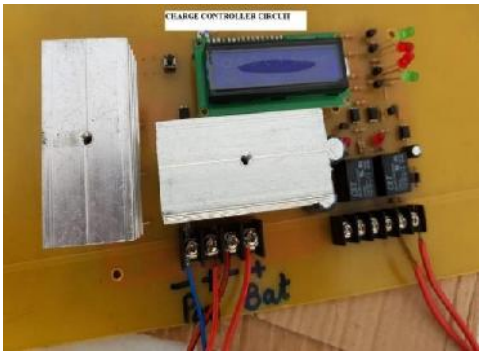

Fig 16: Solar Charge Controller

6. Conclusion

The efficiency and the performance of renewable-energy sources can be harnessed further by the development of the maximum power point tracking and the battery charging control techniques. The proposed hybrid charge controller will be reliable and will accurately charge batteries through solar panel via sun light in day time and also charge batteries through any A.C supply in night time or in cloudy days. So we can use generated electricity for daily life and domestic purpose. Renewable energy solutions are becoming increasingly popular. Photo voltaic systems are good

examples of this. In order to implement a solar system, need of good charge controller is necessary for good efficiency and performance of our system. So hybrid charge controller is one of the best options to employ it in solar systems. Due to availability of hybrid charge controller we can charge our battery either by solar energy in day time or charge our batteries by an A.C supply in cloudy days and in night time. So it is very beneficial for such application.

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Preparation and Investigation of Coal Slurry Fuel Blended with Industrial Wastewater for use in Thermal Power Generation

Mueed Akhtar[1], Ehsan Ali[1]

Abstract:

The scientific novelty of the research is that coal slurry fuels have been prepared by blending pulverized coal with industrial effluents and characteristics were compared with the slurry comprising fresh water. This innovative technique results in saving fresh water. Also, this methodology puts local coal reserves of Pakistan to use in an innovative way which is both efficient and friendlier. This novel idea puts local coal in use for power production. The coal in Pakistan in not in use because of the difficulties in mining and also due to the lack of concern of the government regarding using countries own resources for power production. Instead the policies regarding importing expensive fuels from Gulf States are a common practice. The novelty of this idea serves the idea of both greener and sustainability of energy.

Keywords**:** *Coal, Coal slurry Fuel, waste water*

1. Introduction

Pakistan is majorly an agriculture-based economy but in the past decade there has been a major development in the industrial sector. This industrial development results in more energy requirements and more consumption. In Pakistan total installed capacity of power generation is 22,000 MW. Average production of power is almost 17,000 MW and the shortfall of energy lies between 5,000 MW to 6,000 MW. Total 80.7% of the supply in the energy mix of Pakistan is dominated by oil and gas combined. In fiscal year 2013-2014 energy production from oil was 32% of the total energy mix. From gas 34% of the total energy mix is produced. From coal 3,590,386 TOE were generated and it was 0.1% of the total energy mix. Besides fossil fuels, the other major source of energy is hydel from which total of 30% of the total energy mix. Rest is obtained by nuclear and other resources like renewables and LPG etc.[1].

In Pakistan, vast quantities of coal are present. Each province has got substantial amount of coal reserves. Reserves and their calorific values are shown in the table below.

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TABLE I. Coal Reserves

Province	Reserves (million tons of coal)	Calorific value (BTU/Lb)
Sindh	1,84,623	5,219-13,555
Baluchistan	217	9,637-15,499
Punjab	235	9,472-15,801
KPK	91	9,386-14,217
AJK	9	7,336-12,338
Total	185,175	

From the above data it is quite clear that Pakistan has more than enough coal resources. With these resources Pakistan can generate 100,000 MW of energy for more or less 30 years. In Pakistan most of the coal found has either high Sulphur values or high moisture content. If the coal has perfect quantities of all the components, the coal is in very little quantities. It is clear that the largest coal reserve in Sindh is Thar coal which 175.5 billion out of 184 billion of total reserves of Sindh. But it contains 29.60-55.50% moisture. Total coal reserves in Baluchistan are 217 million tons out of which 32 million tones are considered to be mineable. The classification of coal is sub-bituminous to bituminous. Heating values are in the range of 9,637-15,499 Btu/lb with low ash contents but high sulfur contents. Now talking about Punjab, the total coal reserve is reported to be 22 million tons. It has relatively low moisture, ash content and sulfur content than salt range coal mine, but still not up to mark the optimum quality coal. Quality of coal is also qualified as sub-bituminous coal. In KPK, there are combined reserves estimated to be 91 million tons. Coal of both mines is reported to be sub-bituminous with heating values in the range of 9,386-14,217 Btu/lb. Coal from both mines have low Sulphur and ash contents also with low moisture contents[2].

1.1 Environmental Issues

Pakistan is a developing country. In Pakistan, there are multiple industries, growing day by day. Also the population of Pakistan is increasing day by day. Pakistan is now the home of more than 200 million people. Increased population means more energy requirement, more consumer products, more industrial growth, also more municipal waste and industrial waste. Pakistan is basically an agriculture-based economy but now this economy is shifting towards industry. There are textile mills, sugar mills, cement plants, fertilizer plants, consumer products industry, and food & beverage industry. All these industries use water for processing. If water is used for processing, obviously there is some water wastage.

Pakistan is a country where most of its energy is produced from fossil fuels like oil and gas. A very less amount of energy is produced from renewables. In the recent years there is a remarkable shift in the government's policy, to make the process of making energy efficient, green, cleaner and sustainable.

To have a long term sustainable better economy, Pakistan must address the environmental challenges which comes along with a better and stable economy. These problems include industrial waste water, municipal waste water, chemical spills in clean water, soil erosion, deforestation, salinity, water logging, fresh water pollution, just to name a few.

1.1.1 Water pollution

In Pakistan, water gets polluted by a number of means. Mainly these are classified into following classes.

- Water pollution due to raw sewage.
- Water pollution due to industrial waste water.
- Water pollution due to agriculture run-offs.

All these pollutions have driven fresh water supply to a limited amount. Majority of the population does not have proper supply of fresh drinking water. Urbanization and implementation of modern technologies is also causing the pollution of water. According to the research conducted by Pakistan Medical Research Council, majority of the diseases in common population is caused by drinking of substandard or polluted water. This water

pollution is causing many diseases like typhoid, cholera and other gastric diseases. This polluted water when seeps through the soil, mixed with pockets of fresh underground water also makes it polluted[3].

1.2 Coal Water Slurry Fuel

CWS is a fuel which consists of finely pulverized (less than 20 micrometers in diameter) coal particles suspended in water in the presence of emulsifying agents/oil/stabilizers. CWS usually consists of 55-70% of pulverized dispersed coal particles and 30-45% of water. Coal-water slurry fuel classified based on following properties: ignition temperature 800—850 °C, combustion temperature 950—1150°C, and calorific value 5800-6500 kcal/kg. This fuel can be used to fire boilers for steam production. Another application for this type of slurry is gasification. At present there are multiple gasification processes developed to utilize this technology like GE energy (Texaco), opposed multi-burner process, etc.[4].

The most desirable features of CWSF are high solid loading, good stability, good rheological behavior, low viscosity, low ash content and relatively high heating values. Usually CWSF is prepared by maintaining a solid to water loading of 70% and 30% respectively. These ratios may vary from 70:30 – 60:40. If water is added above 40%, then heating value of the fuel will be decreased. A small percentage (up to 1%) of additives is also added for better dispersion, uniformity and stability of solid loading[5].

2. Materials and methods

Coal was obtained from Pioneer Cement Pvt. Ltd Plant located near Khushab district, Pakistan. They imported the coal from Waterberg coal field located in South Africa. The coal obtained was already pulverized and the average particle size was 90µm. This coal was mixed with three different industrial waste waters. Spent wash was obtained from Noon Sugar Mills Distillery Pvt. Ltd located in Bhalwal near Sargodha district, Pakistan. Similarly, waste water was obtained from Fauji Foods located in Bhalwal near Sargodha district, Pakistan and Sapphire textile mills limited located in Lahore, Pakistan. An ionic surfactant named as sodium naphthalene sulfonate formaldehyde condensate was selected as dispersant which was imported from SHANDONG WANSHAN CHEMICAL CO. Ltd., China and Sodium lingo-sulfite was selected as the stabilizer which was imported from Jinan Yuan sheng Chemical Technology Co., Ltd, China. All the raw materials were collected and brought to the Bio Fuels lab at USPCAS-E NUST, Islamabad Pakistan. For both types of slurries solid loading was kept 65% and liquid ratio was kept 35% by weight. 1% additives were added, both in equal quantities. 400g samples of both slurries were prepared in a mixer driven by 800w variable speed motor. 260g of coal, 139g of water, 0.5g of NaNSF and 0.5g of sodium lignosulfite were added into the container and then mixed at 1357 RPM for 30 minutes. After 30 minutes the coal water slurry fuel (CWSF) was collected into sample bottles. The same procedure was repeated with waste waters to make coal waste water slurry fuels (CWWSF) under ambient conditions.

3. Results and Discussions

After preparing samples of all the slurries, these samples were sent to Pioneer Cement for testing. Three types of tests were performed on both the samples. The tests carried out were focused on finding out the qualities of the fuel in order to determine whether or not it could be used effectively.

A number of tests were performed to determine the quality of coal. These tests include % total moisture (ISO 11722), % Ash content (ISO 1171), % Sulphur (ISO 351), % inherent moisture (ISO 331), % volatile matter (ISO 351) and Calorific value (ISO 1928). All the samples were prepared at Pioneer Cement. As all of them were prepared from finely pulverized coal, now size reduction for the preparation of samples were needed. All the samples were dried by placing them in an air circulated furnace a 40 degree Celsius. After performing the analysis, the following analysis were obtained.

TABLE II. Analysis of Coal, CWSF and CWWSF samples

Sr. No.	Analysis	Coal	Coal Water Slurry Fuel	Coal Waste Water Slurry Fuel (Textile)	Coal Waste Water Slurry Fuel(Alcohol Distillery)	Coal Waste Water Slurry Fuel (Dairy)
1	% Inherent Moisture	-	2.46	1.77	1.42	1.48
2	% Total Moisture	3.12	38.94	39.45	35.54	38.22
3	% ASH Content	16.22	16.72	16.56	17.86	16.80
4	% Volatile Matter	30.69	30.64	27.01	28.41	26.99
5	% Sulphur	0.69	0.81	0.83	0.96	0.85
6	Gross Calorific Value (cal\gm)ADB	6260	6245	6228	6014	6209

In the above table, there are given the properties of five samples. One being the coal and other four are coal slurry fuels. Coal is marked as a basic standard and all other values are for comparison. All the samples of coal slurry fuel have inherent moisture. This is due to the presence of water in the form of fresh water or in the form of waste water. Also due to this same reason the total moisture in the coal slurry samples is higher.

Ash contents of all the samples are almost the same as that of coal sample except the CWWSF (Alcohol Distillery). This is because of the properties of alcohol distillery spent wash. Spent wash already contains solid material. Volatile material in CWSF is in accordance with the coal sample. But for CWWSF sample the levels are different. This is again due to the different properties of different waste waters. Sulphur content in coal sample is 0.69%. This value is perfect for use in thermal power generation. It should be less than 1%. In CWWSF sample this value is different but all the values are within the range. Coal sample has the maximum GCV, all CWWSF samples have lowered GCVs but this difference is negligible.

4. Recommendations

On the basis of all the above discussions it is obvious that all the samples CWWSF are feasible for use in thermal power production. This solves many problems. The Coal Slurry fuels are easy to handle. They have better combustion efficiencies. Ash formation after combustion is less. SOx emissions after combustion is also low. This is because of its composition. It contains water which forms acids with sulphur. Due to these acids formation there are low SOx emissions. Also NOx emissions are reduced due to the presence of water in the slurry. The slurry is combusted at lower temperatures. NOx are produced due to the combustion at high temperatures. This is the only reason of low NOx productions.[6] But there is also a down side. We need to make modifications in the internal design of the existing and new boiler\steam generation systems. Corrosion is accelerated due to the production of acids during combustion. This is a serious problem. It shortens the life of equipment increases, wear and tear. If not inspected and evaluated, it may cause serious damage to internal parts of the boiler/steam generator. It also makes maintenance of equipment more difficult. To prevent this, we need to preinstall an anti-corrosive coating on the internal parts of the boiler/steam generator. Plus, if we replace this fuel in existing systems, we need to make major modifications in the design. For example, if the existing system is on furnace oil, we need to install a new CSF based burner. Also some modification is need to extract ash from the system. The same modifications are

needed if Natural gas based thermal systems are installed. Mostly if natural gas based systems are installed, they use gas turbines instead of boilers/ steam generators. Some modifications are also required in the process. The wet milling equipment is required to prepare the slurry. Also some slurry pumps are required for pumping and transport. A suggested flow sheet diagram is shown below.

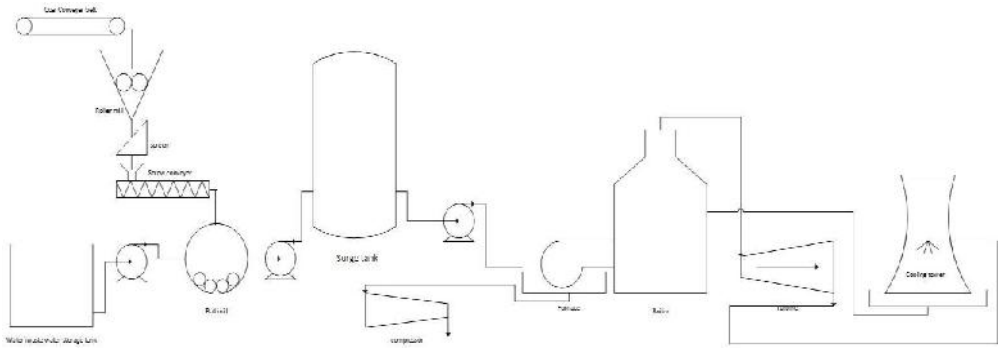

Fig 1: Flow sheet diagram

According to some literature energy production from CWSF is cheaper than Furnace oil and Gas.

TABLE III: Cost comparison

Sr. No	Fuel	Price\MJ (PKR)
1	Furnace oil	2.6
2	Natural Gas	0.63
3	CWSF	0.42

Although there is a very small difference between Natural gas and CWSF, gas reserves in Pakistan are depleting. Government is trying to import LNG as a solution but it is expensive. So this difference will not be very little if compared with LNG[7].

5. Conclusion

Energy production and waste water treatment are two major issues in the world and especially for Pakistan. Energy production from coal is usually avoided due to its environmental hazards. But according to the depleting conditions of other two resources (oil and gas). We need to divert the production of energy from oil and gas to coal to balance it out and to make it somewhat sustainable. Coal gasification, coal to liquid technologies are some of the greener technologies but they are very expensive. Instead Coal Slurry fuel technology is much cheaper and feasible and if we use waste water instead of fresh water then the problem can be addressed for waste water treatment or waste water disposal. From the experiments conducted following points can be concluded.

- All the properties of CWWSF are in accordance with coal sample, which means the CWWSF are viable for use in thermal power production.
- Some capital investment is required for retrofitting the existing systems and acquiring new systems.
- Ash formed is best fit to be used as filler in the production of concrete.
- Per MJ of energy cost of production from CWSF is less than when produced from furnace oil and natural gas.
- Less Sox and NOx emissions are recorded by using this fuel.

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Efficient Topology of Voltage Source Inverter with Reduced number of Transistors

Iqbal Tarique[1], Jahangir Badar Soomro[1], Ishfa Taqi[1], Syed Ali Hyder[1], Faheem A. Chachar[1]

Abstract:

An advanced topology of Voltage Source Inverter has been introduced in this paper. The usage of low-cost switching devices such as Thyristor give some edge to improved topology over conventional topology. The traditional topology requires six transistor, whereas on the contrary it possess only three high performance transistors. The conventional topology could prove to be expensive for high power applications where costly switching devices such as silicon carbide and gallium nitride are required thus, the new evolving topology could be more feasible for it. Simulation and experimental results have been provided for further verification.

Keywords: *Efficient Topology, Inverter, VSI, Transistor, Thyristor*

1. Introduction

Semiconductor devices like bipolar junction transistors, MOSFETs, Thyristors, Triac and Diac, etc. make our lives easier. They act as an intermediate between various forms of energies and convert one form of power into another form. These all small devices combine together and make a huge sea of revolutionary machines. Initially electromechanical converters derived one form of energy into another form. Inverter is basically a converter which convert DC power into AC power. The word "inverter" is derived from a class of power electronics circuits which could be able to operate from a DC voltage source or DC current source and convert it into AC voltage or AC current [1-3]. Although it is not unusual that the input DC supply could get from the AC source the primary source is AC, it is converter from AC to DC converter into DC form and then converted back to AC using an inverter. Since the resultant output might be different in frequency and magnitude from the initial AC supply [4]. Now a days, we use a common topology which we call it conventional topology here and it is shown in Figure 1. It is widely used in many applications like Un-interruptible Power Supply (UPS), Industrial motor drives, HVDC etc. This paper focused on the proposal of three-phase voltage source inverter (VSI) which has similar features compared to the conventional topology of six switches (transistor) in terms of voltage-current waveforms. In this paper, a topology is introduced which has a major reduction of transistors and instead of these inexpensive thyristors are used shown in Figure 2.

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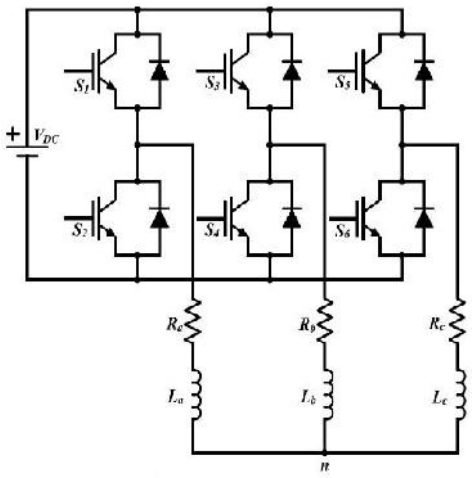

Fig 1: Schematic model of proposed topology

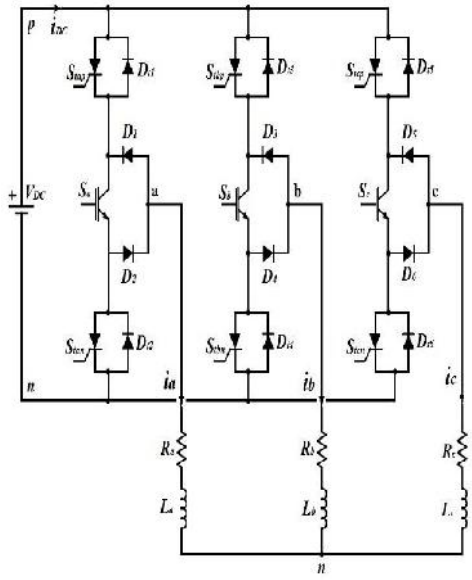

Fig 2: Schematic model of Conventional topology

This paper discusses the proposed topology, its basic operation and switching technique. Software implementation of the topology is implemented using MATLAB/SIMULINK and also its Experimental results are provided to analyse and verify its feasibility and performance.

2. Proposed Topology

Inverters are power electronics converters which convert Direct Current (DC) into Alternating Current (AC) utilized extensively in many applications such as induction heating, variable speed AC motor derives Distributed Generation (DG) and Uninterrupted Power Supplies (UPS).

Semiconductor electronic switches are one of the major components of the converter which essentially determine the complexity, cost and efficiency of the system. Mostly, silicon-based power electronic switches are widely used in the market [5].

Here the proposed novel topology of three leg Voltage Source Inverter (VSI) (shown in Figure 2) which possesses three semiconductor transistors unlike the conventional topology which contain six semiconductor transistors. This makes this topology cost effective [6]. Thyristors are also present per phase to provide natural commutation Therefore, there is no need of external commutation circuitry. This topology is more efficient and cost effective than conventional topologies of Voltage Source Inverters (VSI).

3. Commutation Scheme for Novel Topology

It includes switching elements like transistors and thyristors which require a proper switching technique to drive the required results. Commutation speed of such devices could be controllable. Direction of positive and negative current flow will be discussed in this section. Only one phase of this topology will be elaborated here in order to understand its functionality properly [7].

A. Basic commutation operation

a) Positive Current Control Scheme

i For positive cycle of current flow, thyristor Stap will remain on while keeping the complimentary thyristor Stan off. As shown in the Figure 3(a).

ii With the help of an appropriate PWM technique transistor Sa will continuously turn on and off.

iii Positive current direction remains through Stap, Sa, D2, and Dt2, in the whole positive current cycle.

iv At zero crossing of a single period, the gate signal from transistor Sa should be removed to turn off the thyristor Stap

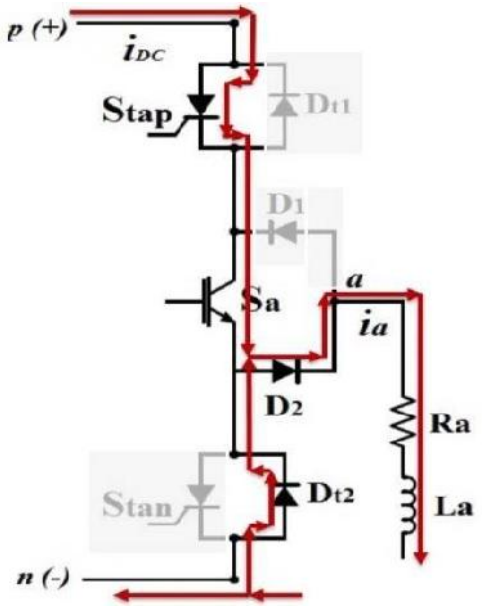

Fig 3(a): Current Control Scheme for Single Phase

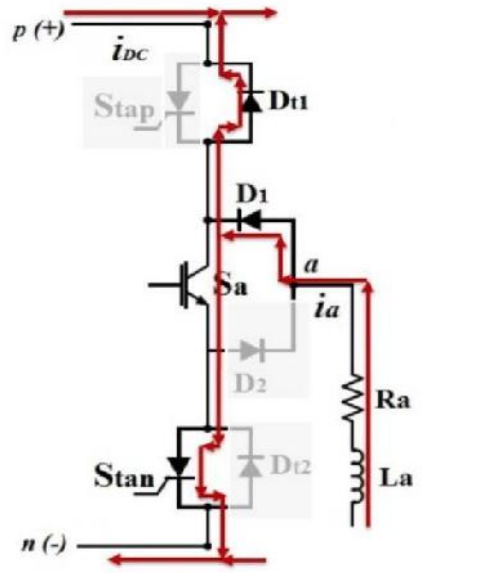

Fig 3(b): Current Control Scheme for Single Phase

b) Negative Current Control Scheme

i For negative cycle of current flow, thyristor Stap will remain on while keeping the complimentary thyristor Stap off. As shown in the Fig 3(b).

ii With the help of an appropriate PWM technique transistor Sa will continuously turn on and off.

iii Current direction Negative remains through Stan, Sa, D1, and Dt1, in the whole positive current cycle.

iv For remaining stages, the same process will be repeated with respect to their phase order.

4. Switching States of Novel Topology

This Novel Topology of VSI which contain three stages (three legs) has total eight active and zero voltage commutation stages like conventional topology. In Figure 4(a) to Figure 4(f), only the active elements and the path of current flow are elaborated here. These are the six active commutation stages. At each stage there is only single thyristor and a transistor will be turned on for conduction of a phase. On the other side, the opposite thyristor of the same stage cannot conduct.

In Figure 4(a) the thyristor of third leg is conducted while its complementary thyristor remains off. When thyristor of second stage in Figure 4(b) is on, at that instance the other thyristors for positive current should be off. As shown in the Figure 4(a) only one thyristor Stcp is in conduction mode, while Stap and Stbp is turned off. The complimentary thyristors are switched on and fired off in accordance with the thyristor of same leg. As per the rule, when Stcn is off Stan and Stbn should be fired on. However, the three transistors Sa, Sb, Sc will be turned off when current reaches zero with respect to their phase. The path through thyristor Stcp, Stan, and Stbn; transistor Sa, Sb, and Sc; also, diode D1, D3, D6, Dt1, Dt3, and Dt6 followed by the current at this stage. The next commutation scheme and current flowing paths are examined in Figure 4(b) in which the active or conducted devices are shown. In addition, the pictorial description is present for the rest stages from Figure 4(c) to Figure 4(f).

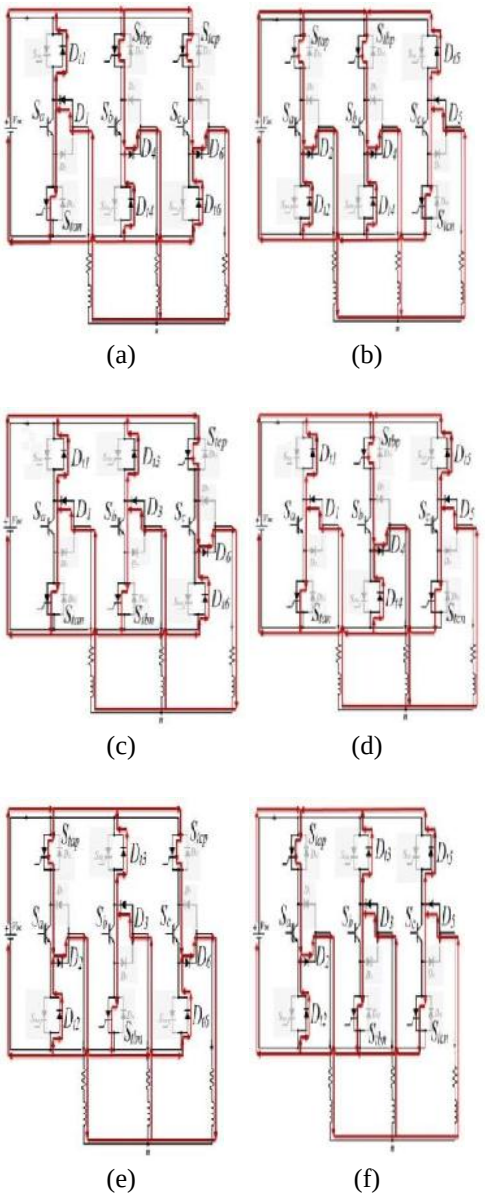

Fig 4: Switching States of Novel Topology

The firing sequence (switching scheme) for all thyristors and transistors are elaborated clearly in Figure 5, where the dead period between the switching of thyristors present at the same leg (Stap and Stan, Stbp and Stbn, Stcp and Stcn) is specified by the red bold mark. The transistor present in each stage is continuously commutated on and off by an appropriate PWM techniques. When this switching pulse is removed from transistors, the dead period will be generated between the commutation sequences of thyristors. It behaves in a way that when triggering signal is removed from the transistor, the circuit acts as an open path At that time,current could not flow through the circuit. According to the commutation sequence the elimination of gate pulse from transistor switched off the thyristor and provided them an appropriate recovery time for the next stage. Below the conduction periods of semiconductor devices are illustrated in an adequate way [8].

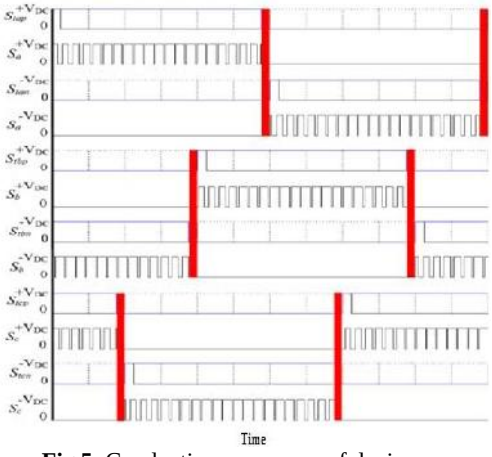

Fig 5. Conduction sequences of devices

According to the way of commutation illustrated in Fig 4(a) to Fig 4(f), it can be analysed that the switching sequences are:

$$Stap.Sa+Stan.Sa= 1 \quad (1)$$

$$Stbp.Sb+Stbn.Sb = 1 \quad (2)$$

$$Stcp.Sc+Stcn.Sc= 1 \quad (3)$$

The table I, elaborates the eight switching states of inverter. Non-zero out AC line voltage generated by seven stages and the rest two stages: stage 1 and stage 8 generate zero AC line voltage. The resultant line to line AC output voltage have discrete values of Vdc, 0, and –Vdc. Output line voltages are shown with respect to the conduction of their devices.

TABLE I. Switching states of devices

Switching States	Devices			Output Line Voltages		
	Stap.Sa	Stb.Sb	Stcp.Sc	Vab	Vbc	Vca
1	0	0	0	0	0	0
2	0	0	1	0	-Vdc	Vdc
3	0	1	0	-Vdc	Vdc	0
4	0	1	1	-Vdc	0	-Vdc
5	1	0	0	Vdc	0	-Vdc
6	1	0	1	Vdc	-Vdc	0
7	1	1	0	0	Vdc	Vdc
8	1	1	1	0	0	0

5. Switching Control Scheme

It is defined before that the transistors present at the middle of each leg is commutated on and off with any specific switching scheme. Any commutation technique/triggering scheme could be utilized to provide gate pulses to the transistors. However, in this project a uniquely designed PWM scheme was generated through Sine-Triangle PWM scheme. In this method a primary Sinusoidal waveform is compared with a triangular waveform.

The same gate pulse is applied to the transistor during positive and negative cycle of waveform in order to provide commutation from positive to negative current of thyristor at each phase. For easily understanding the analytical behaviour, it is assumed that the delay between each phase of thyristor is eliminated. During the shifting from positive to negative cycle of current, the gate pulse provided to the transistor also have no dead time. At the end, combination of all these elements will result an appropriate control scheme. The control scheme is generated by the comparison of triangular carrier wave with sinusoidal waveform which is 120^0 shifted from each other for each phase.

a) Stage 1 Control Scheme

Figure 6(a) shows the comparison of sinusoidal and triangular wave which results the generation of triggering pulse for middle transistor Sa illustrated in Figure 6(c) and Figure 6(e). In addition, step pulse for firing thyristor Stap and Stan is elaborated in Figure. 6(b) and Figure 6(d) respectively.

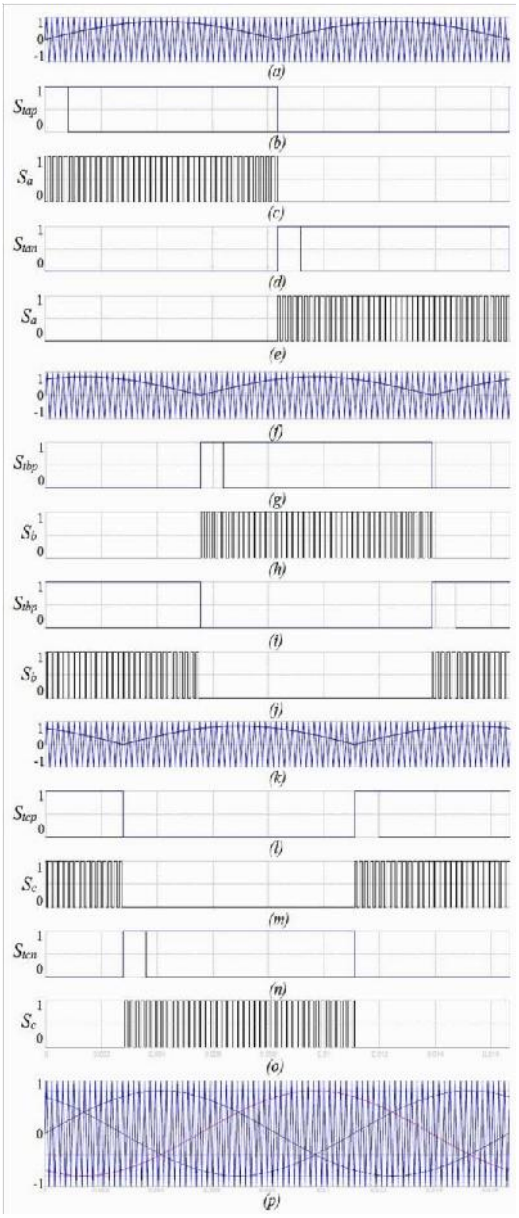

Fig 6: Switching Control Scheme for stage 1, 2 and 3

b) Stage 2 Control Scheme

Switching sequence for stage 2 could also analyze in the Figure 6. In which Figure 6(g) and Figure 6(i) are exciting pulse for thyristor Stbp and Stbn respectively. The output switching gate pulse derived from the comparison of Triangular and Sinusoidal waveform as shown in Figure 6 (f), could be examined in Figure 6 (h) and Figure 6 (j). Here the sine wave has a phase difference of 1200 from previous stage [9-10].

c) Stage 3 Control Scheme

As mentioned earlier, Figure 6 (k) reflects the comparison of sine triangle waveform where sine wave possesses 2400 phase shift than the sine wave used in first stage. Figure 6(l) and Figure 6(n) illustrate the thyristor triggering pulses (Stcp and Stcn). Figure 6(m) and Figure 6(o) illustrate the switching pulse of transistor.

Output Current Equations

The output currents could be assumed that are:

$$i_a = I_o\, Cos(\omega_o t + \varphi_o) \quad (4)$$

$$i_b = I_o\, Cos(\omega_o t + \varphi_o - \tfrac{2\pi}{3}) \quad (5)$$

$$i_c = I_o\, Cos(\omega_o t + \varphi_o + \tfrac{2\pi}{3}) \quad (6)$$

Output Voltage Equations

The inverter output equation is considered as:

$$\begin{pmatrix} Va \\ Vb \\ Vc \end{pmatrix} = \begin{pmatrix} Stap & Stan \\ Stbp & Stbn \\ Stcp & Stcn \end{pmatrix} * \begin{pmatrix} Vp \\ Vn \end{pmatrix} + \begin{pmatrix} Sap & San \\ Sbp & Sbn \\ Scp & Scn \end{pmatrix} * \begin{pmatrix} Vp \\ Vn \end{pmatrix} \quad (7)$$

The value of S would be 1 when the respective switch is on. When the switch is turned off the value of S would be 0.

Equations for Phase Voltage

By using Sine-Triangle PWM scheme equations for the phase voltages could be written as:

$Vax = V_o \,Cos\ \omega_o t = MV_{DC}\, Cos\ \omega_o t$ (8)

$$Vbx = V_o\, Cos(\omega_o t - \tfrac{2\pi}{3}) = MV_{DC}\, Cos(\omega_o t - \tfrac{2\pi}{3}) \quad (9)$$

$$Vcx = V_o\, Cos(\omega_o t + \tfrac{2\pi}{3}) = MV_{DC}\, Cos(\omega_o t + \tfrac{2\pi}{3}) \quad (10)$$

Line-line three phase output voltages can be defined as:

$$V_{ab} = Vax - Vbx = M\ \sqrt{3}\ V_{DC}\, Cos\ (\omega_o t + \tfrac{\pi}{6}) \quad (11)$$

$$V_{bc} = Vbx - Vcx = M\ \sqrt{3}\ V_{DC}\, Cos(\omega_o t - \tfrac{\pi}{2}) \quad (12)$$

$$V_{ca} = Vcx - Vax = M\ \sqrt{3}\ V_{DC}\, Cos(\omega_o t + \tfrac{5\pi}{6}) \quad (13)$$

In the above equations

M = Modulation index = V_o / V_{DC}

V_o = peak amplitude of output voltage [13].

Hence, through these switching patterns it is understandable the working principle of three leg three phase voltage source inverter.

6. Simulation Results

The Novel topology is implemented using MATLAB/SIMULINK shown in Figure. 7. Simulation has been performed to observe the output current, Line voltages and Total Harmonic Distortion (THD). All the switches and the components as ideal. Simulation parameters taken for analysis are as follows:

Input

DC Voltage: 200 V (Peak to Peak)

Output

Inductance: 25 mH;

Output Resistance: 10 Ω;

Carrier Frequency: 2400 Hz:

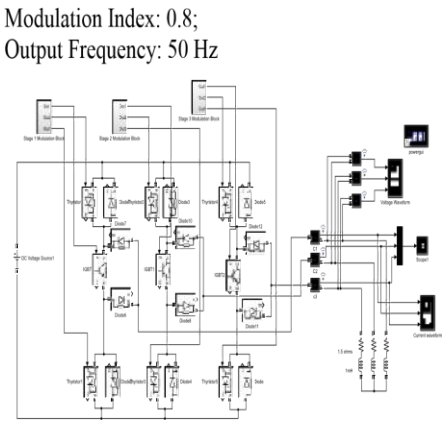

Fig 7:.MATLAB/Simulink Model of VSI

THD without Filter is 45.13%

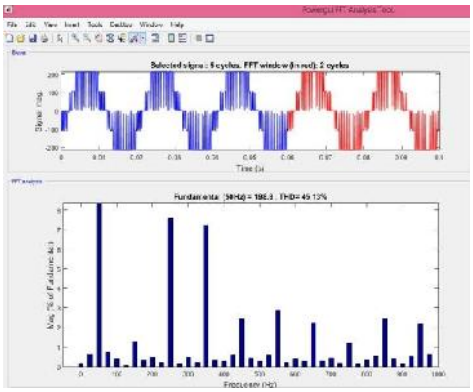

Fig 8(a): THD of Voltage Waveform without Filter

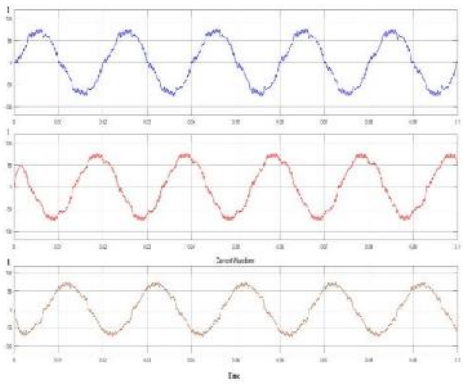

Fig 8(b): Output Current Waveform without Filter

THD of current with RL load is 10.6% without filter.

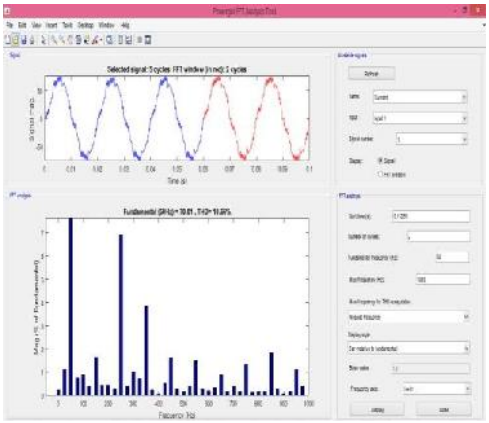

Fig 8(c): Current THD with RL load without filter

After using filter, we get the results given below

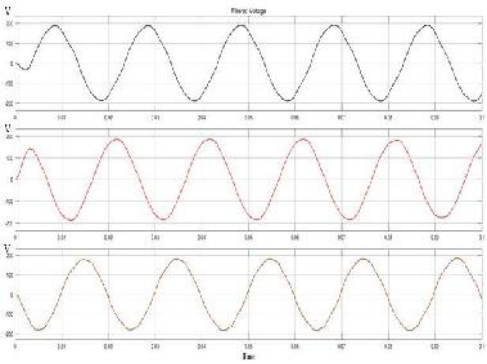

Fig 9(a): Voltage Waveform after Filtration

THD of Voltage waveform after filtration that is 3.03%

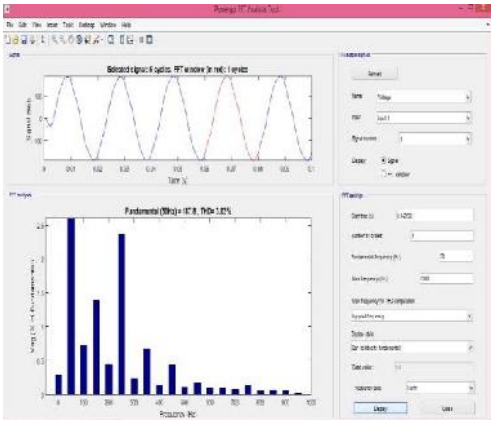

Fig 9(b): Voltage THD after Filtration

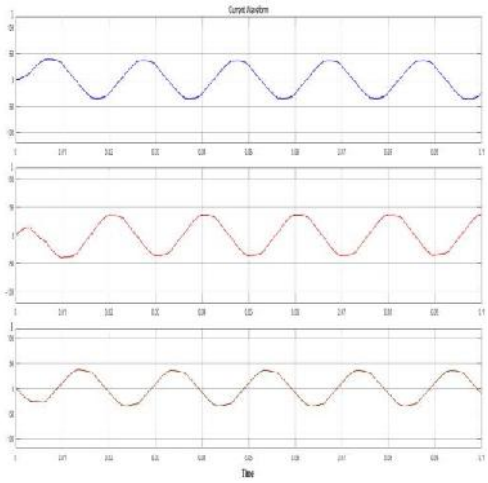

Fig 9(c): Current waveform after Filtration

Current THD after filtration is 2.89%

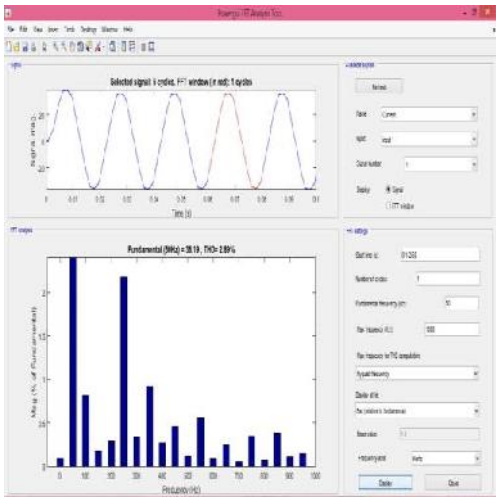

Fig 9(d): Current THD after Filtration.

Finally, Figure 8(a) shows the output three-phase line voltages and Figure 8(b) shows the output three-phase current waveform without filter. All the outputs are taken as a PWM technique which can be further improved by using different technique. Also, results are shown with filter in Figure 9(a) and Figure 9(b) three-phase line voltages and THD of filtered voltage respectively. Figure 9(c) and Figure 9(d) shows three-phase filtered current waveform and THD of current waveform.

7. Hardware Results

This Novel topology of Voltage Source Inverter is also implemented on hardware to verify the results extracted from the simulation. Switches and components used to implement this topology are as following:

Input DC Voltage: 12-30 V (Peak to Peak)
Output Inductance: 10 mH;
Output Resistance: 1 KΩ;
Output Frequency: 50 Hz;
Arduino UNO: To give switching signal
BT151: Thyristor
IRG4BC40S: Transistor
PN-Junction: Diode

Fig 10(a): PCB Board with Components

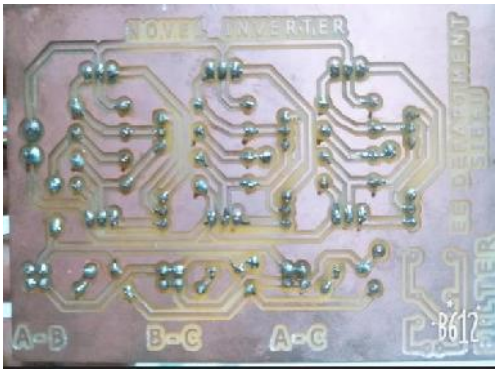

Fig 10(b): Circuit Design on PCB Board

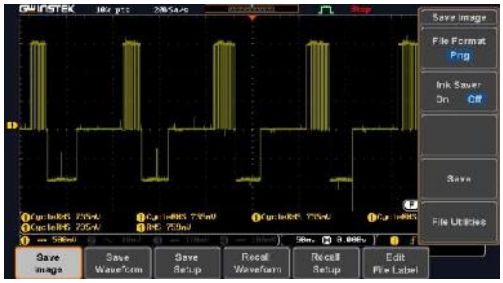

Fig 10(c): Experimental Result of output Waveform

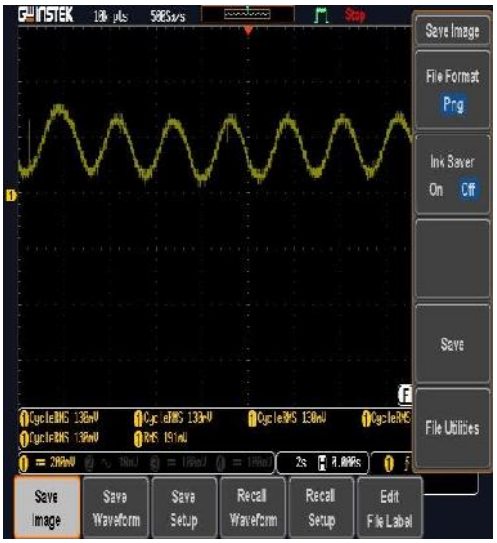

Fig 10(d): Output voltage wave of Novel topology after filtration

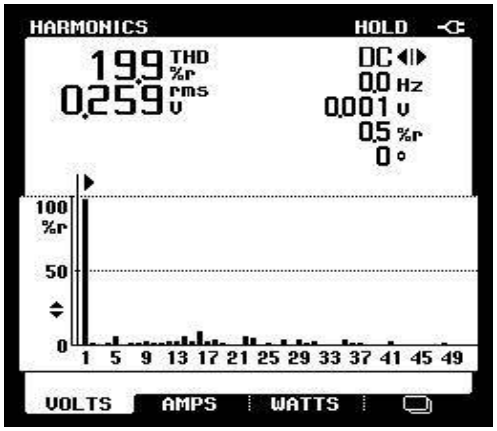

Fig 10(e): THD of filtered output Voltage

After getting output three-phase line voltages, it can be seen that this topology has the same features as the conventional topology in term of voltages. Although the waveforms are slightly distorted, it can be improved by developing and utilizing better switching technique and control scheme. In addition, current wave form will be given soon by implementing new scheme. In future, some steps would be taken to make this topology in use for the domestic as well as commercial use.

8. CONCLUSION

Voltage source (VSI) and current source inverters (CSI) are widely utilized in various applications such as, adjustable speed drives (ASD) for AC motors, induction heating, uninterruptable power supplies (UPS), standby power supplies, electronic frequency changer circuits, distributed generation units, HVDC systems to name a few [11],[12]. From the above results of MATLAB/SIMULATION as well as of hardware results, it can be seen that the novel topology of voltage source inverter has the same features in terms of voltage-current waveforms provided in both sections i-e Simulation and Hardware. Although, some results are distorted, these distortions can be mitigated by using more appropriate switching schemes, controlling schemes and more authentic filtration methods. Observed from above results, the Novel topology has advantages of THD over the conventional inverter as well as it has an advantage of its application that it can be used for high power applications. Furthermore, this topology can be expanded to the domestic purpose as conventional topology is tending for domestic purpose. As the novel topology can be an economical alternative for the domestic purpose, it has a benefit of low cost as compared to the conventional topology. By taking some serious initiatives, this topology can be introduced to the domestic market for the betterment of society. The main purpose of this paper was to realize the importance and advantages of novel topology of voltage source inverter over the conventional topology.

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