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Arduino-Based MOSFET-Based Three-Phase Inverter Suitable for Micro Grid Systems

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***Abstract*— To Fulfill the Demand for Three-Phase Inverters in Micro grid Systems Or Sustainable-Powered Industrial Facilities, A_MOSFET-Based Three-Phase Inverter Has Been Devised and Implemented. This System Efficiently Converts DC Power Into Three-Phase AC, Generating 223V Square Waves At Each Phase From A 12V Battery Through The Switching Of Three Stages Of Power Mosfets. Utilizing PWM Signals From An Arduino Uno R3, Each Stage, Comprising Three MOSFET Units, Totaling Six Mosfets, Conducts The Inversion Process Independently For Each Of The Three Single-Phase Connections. In Addition, Six BJTs Are Integrated Into The System. The Arduino Uno Manages The PWM Signal Generation, Ensuring A 120-Degree Phase Displacement Among Each Phase. Signal Amplification Is Achieved By Employing A Three-Phase Transformer At The Outputs Of The MOSFET Stages. With A 60W Incandescent Light Bulb Serving As A Load For Each Phase, The System Delivers A Voltage Of 386.25V Across The Three-Phase Line, Along With A Current Of 0.58A. Design, Simulation, And Testing Of The Electronic Circuit Were Conducted Using Proteus 8.9 Professional, While The Programming Codes Were Written Using Arduino IDE. The Functionality Of The Designed System Was Practically Evaluated And Tested.**
***Keywords*—MOSFET, Arduino Uno R3, PWM, Three-Phase Inverter, Micro grid, Renewable Energy, Proteus, Arduino IDE.**

INTRODUCTION:

Fossil Fuels Remain The Primary Energy Source Globally, Despite Being A Major Contributor To Environmental Degradation. Consequently, There's A Concerted Effort To Seek Alternatives To Our Current Energy Generation Systems. Additionally, As Society Becomes Increasingly Reliant On Electricity, The Demand For Energy Has Surged, Leading To Challenges Such As Grid Instability And Frequent Power Outages[1]. In Response, There's A Growing Emphasis On Sustainable Technologies And The Development Of More Efficient Power Distribution Systems, With Microgrid Technology Emerging As A Promising Solution[2]. Renewable Energy Sources Like Solar Power, Wind Turbines, And Tidal Energy Can All Integrate into Micro grid Using Appropriate Techniques. Microgrid Offer A Pivotal Approach To Power Distribution And Management, Enabling Households With Renewable Energy Sources To Contribute, Thereby Alleviating Strain On The Grid And Reducing Electricity Costs, Particularly During Peak Hours. However, Since Renewable Energy Sources Primarily Generate DC Power, Inverters Are Essential For Converting It To AC Power To Run Household Appliances And Tools[4]. Inverters, Electronic Devices Capable Of Converting DC To AC Power While Maintaining Desired Voltage And Frequency, Come In Various Configurations, With Single-Phase And Three-Phase Inverters Being The Most Prevalent[5]. The Work Discussed In This Paper Focuses On The Latter, Employing A Three Single-Phase Parallel Inverter Construction Method. Inverters Can Be Broadly Categorized Into Voltage Source Inverters (VSI) And Current Source Inverters (CSI), With This Paper Detailing The Design Of A Pulse-Width Modulated VSI, Which Efficiently Converts Fixed Voltage DC Power Into Variable Frequency AC Power[6].

PWM, Or Pulse-Width Modulation, Is A Technique Employed In Electronics To Achieve The Effect Of Continuously Changing Analog Signals With High Electrical Efficiency[7]. In Electronic Design, Three Common PWM Techniques Are Utilized: Single-Pulse Modulation, Multiple-Pulse Modulation, And Sinusoidal Pulse-Width Modulation. In Inverters, PWM Is Typically Executed Using Power Semiconductor Switches Such As IGBTs, Mosfets, And BJTs, With Various Methods Employed To Produce An Output AC Signal Closely Resembling A Sine Wave. Notably, An Inverter Regulates Only The Frequency Of The Output, While The Input Voltage Determines The Output Magnitude[8]. Output Voltage From An Inverter Can Be Fixed Or Variable At A Fixed Or Variable Frequency. When The DC Input

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Voltage Is Constant And Uncontrollable, Achieving A Variable Output Voltage Is Accomplished By Varying The Frequency Of The Inverter, Typically Through PWM Techniques. Although The Output Waveform Of An Inverter Is Not Inherently Sinusoidal, It Can Be Engineered To Closely Approximate One Through Various Techniques. PWM Techniques Are Applied Similarly In Both Single-Phase And Three-Phase Inverters, Albeit With Simultaneous Modulation For Each Phase And Varying Angular Displacements, Such As 120 Degrees, 150 Degrees, Or 180 Degrees, Depending On The Desired Electrical Efficiency. In The Presented Work, Single-Pulse Modulation With A 120-Degree Displacement Is Employed, Utilizing Mosfets For Implementation[9]. PWM Signals Can Be Generated Using Different Methods, Including Op-Amps, 555 Timers, Microcontrollers, Or Arduino. Arduino, An Open-Source Platform Featuring A Microcontroller Chip, Offers An Inexpensive And User-Friendly Approach To Programming Electronic Devices For Interaction With Their Environment Through Sensors Or Other Input Means[10]. In This Work, An Arduino Uno R3 Is Utilized, Featuring 14 Digital Input/output Pins, With 6 Pins Designated For PWM Outputs. R3 with Pin-Outs [11].

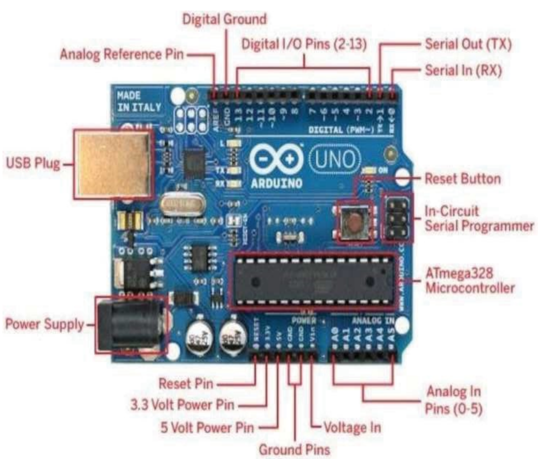

Fig-1 Arduino Uno

II. METHODS & MATERIALS:

A. Components & Peripheral Devices:

The Inverter Design Incorporates Several Essential Components And Peripheral Devices To Function Effectively. These Include:

Arduino Uno: Serves As The Central Control Unit Of The System And Generates PWM Signals.Mosfets: Utilized To Generate Alternating Signals For The Inverter Operation. Transformers: Employed To Step Up The Signals For Amplification.

The Complete List Of Required Components And Peripheral Devices Is Detailed In Table 1.

Devices	Reference/Name	ID / Specification
Power Supply	BATTERY	12V
Arduino	Arduino Uno R3	Atmega328p Based
MOSFET	Q1, Q2, Q3, Q4, Q5, Q6	IRF Z44N (VDS=55V Max, ID=49A Max, ±VGS=20V Max, VGS(TO)=2V Min)
Transformer	3 PHASE Transformer	Primary 12V, Secondary 220V
Lamp (As Load)	Lamp 1 To 3	60W, 220V
Resistors	Resistors 1 To 3	4.70k
BJT	BJT 1 TO 6	BC548-3, BC558-3

Fig-2 COMPONENTS AND PERIPHERAL DEVICES OF THE SYSTEM.

III. ELECTRONIC CIRCUIT / HARDWARE DESIGN:

As Previously Discussed, Constructing A Three-Phase Inverter Involves Separately Inverting Three Single-Phase Connections, Each With A Specific Phase Displacement Among Them. The Three-Phase Inverter Depicted In Figure-3, Is Designed With A 120-Degree Phase Displacement, With PWM Applied To Each Phase Independently By The Arduino. For Simplicity, Each Single-Phase Connection Is Referred To As A Leg. Each Leg Comprises One Power MOSFET (PMOS) And One Power MOSFET (NMOS) Connected To The Two Bjts, All Connected To The Arduino For Inversion Through Switching. The Number Of Mosfets Can Vary Based On Power Requirements. In This Implementation, Two Mosfets Are Used In Each Leg Due To The Relatively Low Power Rating Of The IRF Z44N Model Employed. Additionally, Each Leg Features A Three Phase Step-Up Transformer Coupled With The Output Of The Mosfets To Amplify The Voltage To 219V From An Input Voltage Of 12V.In Figure-3, All Circuit Components, Including The Battery, Arduino, Mosfets, And Transformers, Are Depicted With Their Interconnections Highlighted In Different Colors For Clarity. Three 220V Lamps/Bulbs Serve As Loads To Simulate The Three-Phase Functionality. The Wire Of The Transformer Is Connected To The Positive Terminal Of The Mosfet Bridge Drain, The Sources Of Each Two MOSFET Bridges Are Connected To The Terminal Of The Battery, And The Gates Of The Mosfets Are Linked To The BJTs Bridge, With The Gate Of The BJTs Connected To The Digital Output (PWM) Of The Arduino. When The Arduino Generates Gate Pulses, The

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Mosfets Switch, Converting Direct Current (DC) To Alternating Current (AC), Causing Current To Flow In The Mosfets And Inducing EMF In Each Transformer, Opposing The Battery's EMF. The Transformer Turns Ratio Is Set To Be 0.05H To Step Up 12 Volts To 220 Volts Per Phase. The Electronic Circuit Design Is Executed Using Schematic Capture In Proteus 8.9 Professional.

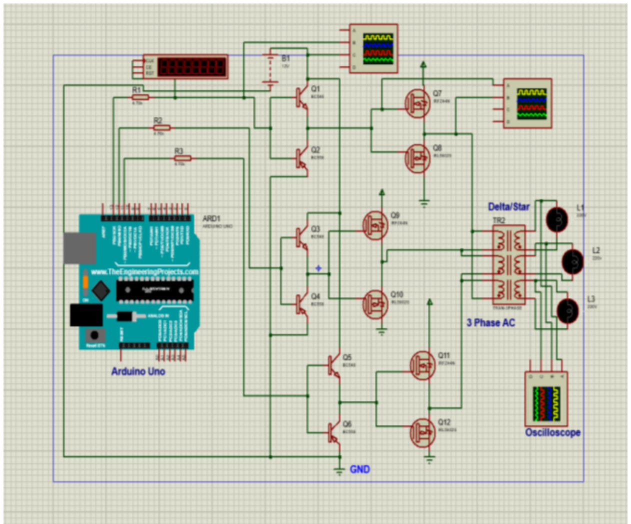
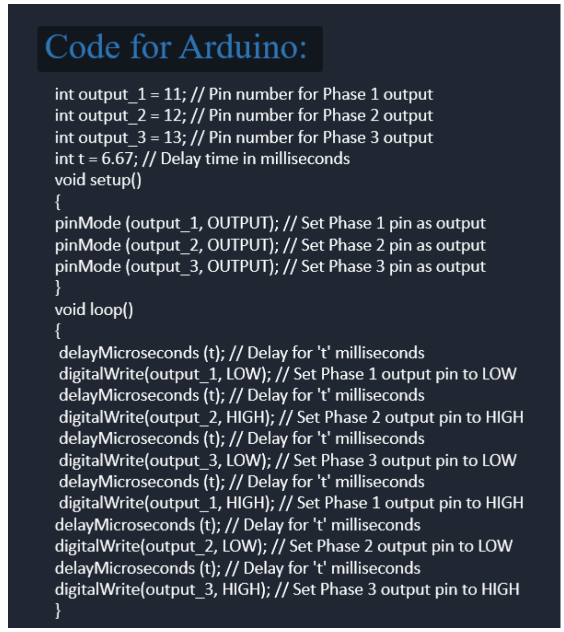


Fig-3 Arduino-Based Three-Phase Inverter

IV. ARDUINO PROGRAMMING:

Arduino Serves As A Microcontroller-Based Platform For Programming Electronic Devices, Utilizing The Atmega328p Microcontroller From Atmel. Consequently, The Functionality Of An Arduino Hinges On The Programming, Which Aligns With The General Attributes Of At Mega Programming. To Generate The PWM Signal Required To Drive The Three MOSFET Bridges For The Inversion Process With A 120-Degree Phase Displacement, Output Pins 9 To 11 Of The Arduino Are Utilized. The Arduino Integrated Development Environment (IDE) Is Employed To Write the Programming Codes. Figure-4 Outlines The Actual Programming Code Utilized For This Purpose.



Code for Arduino:

```
int output_1 = 11; // Pin number for Phase 1 output
int output_2 = 12; // Pin number for Phase 2 output
int output_3 = 13; // Pin number for Phase 3 output
int t = 6.67; // Delay time in milliseconds
void setup()
{
pinMode (output_1, OUTPUT); // Set Phase 1 pin as output
pinMode (output_2, OUTPUT); // Set Phase 2 pin as output
pinMode (output_3, OUTPUT); // Set Phase 3 pin as output
}
void loop()
{
 delayMicroseconds (t); // Delay for 't' milliseconds
 digitalWrite(output_1, LOW); // Set Phase 1 output pin to LOW
 delayMicroseconds (t); // Delay for 't' milliseconds
 digitalWrite(output_2, HIGH); // Set Phase 2 output pin to HIGH
 delayMicroseconds (t); // Delay for 't' milliseconds
 digitalWrite(output_3, LOW); // Set Phase 3 output pin to LOW
 delayMicroseconds (t); // Delay for 't' milliseconds
 digitalWrite(output_1, HIGH); // Set Phase 1 output pin to HIGH
delayMicroseconds (t); // Delay for 't' milliseconds
digitalWrite(output_2, LOW); // Set Phase 2 output pin to LOW
delayMicroseconds (t); // Delay for 't' milliseconds
digitalWrite(output_3, HIGH); // Set Phase 3 output pin to HIGH
}
```

Fig-4 PROGRAMMING CODE OF THE INVERSION SYSTEM

V. RESULTS & DISCUSSION:

A. Simulation Results

To Validate And Explore The Functionality Of The System Outlined In This Paper, Simulations Are Conducted Using Proteus 8.9 Professional. The Results Are Cross-Referenced With The Programmed Codes And The System's Operational Principles, Confirming Their Alignment With The Expected Outcomes. A Screenshot Of The Simulation, Illustrating The Operational Analysis, Is Presented In Figure 10. The Visualization Depicts Three Lamps/Bulbs Illuminating, Affirming The Individual Inversion Processes Are Functioning Correctly. In Addition To Operational Analysis, The Transient Responses Of The System Are Scrutinized And Confirmed In Proteus. Input-Output Signals Are Plotted To Ensure That The Signal Responses Adhere To The Design Specifications. The Obtained Results, Depicted In Figure 5 Through Figure 8, Demonstrate That The Transistors Are Generating Square (AC) Waves From DC Input While Maintaining A 120-Degree Phase Displacement Among The Three Individual Phases. Furthermore, The Resultant Current-Voltage Parameters Obtained From The Proteus Simulation Are Tabulated In Table 3, Providing Comprehensive Insights Into The System's Performance.

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Fig: 5 Output For Arduino Pulse

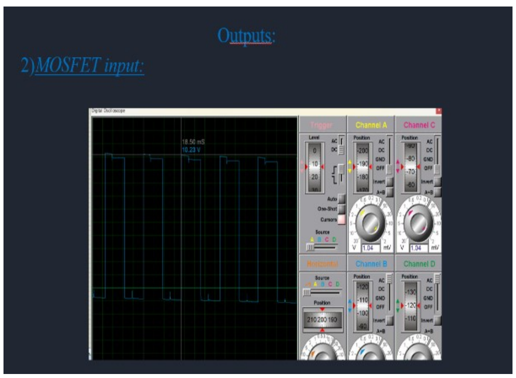

Fig: 6 Output For Mosfet Input

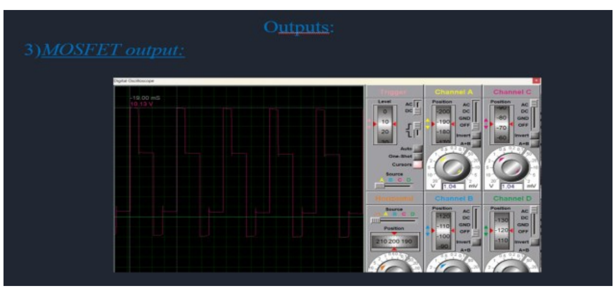

Fig: 7 Output For Mosfet Output

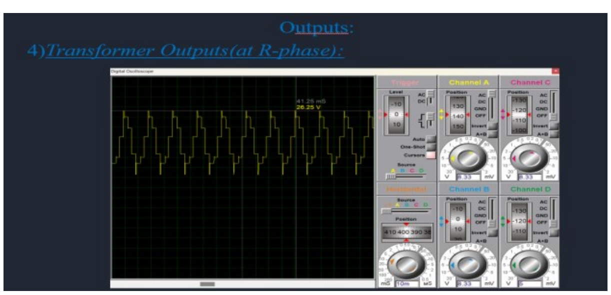

Fig: 8 Output Of Transformer At R-Phase

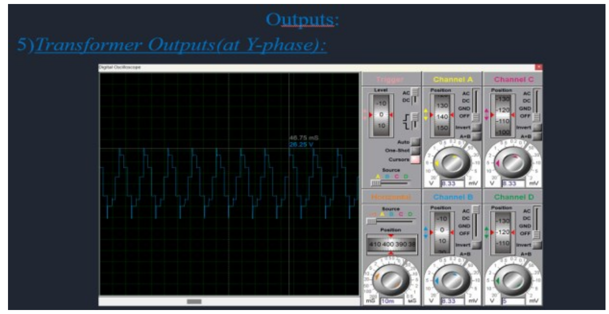

Fig: 9 Output Of Transformer At Y-Phase

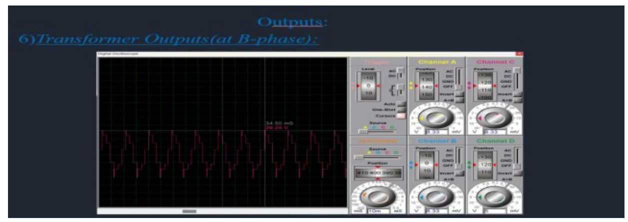

Fig: 10 Output Of Transformer At B-Phase

VI. CONCLUSION:

A MOSFET-Based Three-Phase Inverter, Coupled With Arduino, Efficiently Generates 223V Quasi-Square Waves From A 12V Battery. Verified For Functionality, It Proves Ideal For Micro Grid Systems. With 6 Mosfets Powering Three Single-Phase Connections, The System Can Be Optimized To Just 2 High-Powered Mosfets. Operating At 386.25V for Three-Phase and 223V For Single-Phase, It Delivers 0.58A Current. Its Versatility Makes It Suitable For Small Industrial Facilities Requiring Three-Phase Connections, Marking A Significant Step Towards Energy Efficiency And Sustainability.

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