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Multipurpose Scheme of Workshop Exhaust System for Ventilation and Electrical Power Generation

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Abstract

This paper represents the multipurpose scheme for workshop roof exhaust system. With the help of this concept we can use workshop exhaust system for ventilation purpose as well as electricity generation. This system operates on renewable energy source i.e. wind power. Whenever wind strikes on turbine, it will rotate due to kinetic energy of wind. Here, exhaust fan is connected with turbine, so it will also rotate and sucks hot air inside the workshop and exhausted into outer atmosphere. During all of this process there is no electricity consumption but there is electricity generation using a new innovative technique. Arrangement of Permanent magnets is connected with turbine. And fixed windings are also placed to the upper and bottom side of the magnet disc. Whenever magnetic disc rotate with the rotation of turbine, there will be variation in magnetic field. Due to this rate of change of magnetic flux, electro motive force is induced in windings according to faraday's law of electromagnetic induction. Thus with the rotation of turbine, there will be two process taking place at the same time i.e., ventilation and electricity generation.
Keywords: Multipurpose Scheme, Renewable Energy Sources, Renewable Energy Electricity Generation, Workshop Exhaust System, Workshop Roof Top Ventilation, Ventilation System, Turbine Ventilator, Electric Power Generation, Wind Power, Wind Power Electricity Generation, windmill, wind farm

I. INTRODUCTION

From the beginning of electricity generation, we are trying to make electricity generation more efficient and economical. For that we have to implement some new techniques and reduce generation and transmission losses. We all are know that non-renewable energy sources has its own limitations or we can say limited availability on earth. So implementation of electricity generation for non-renewable energy sources will not useful for our next generation. So that we have to implement new techniques for renewable energy sources because of its lifelong availability. In India, potential of wind power is much higher than other renewable energy sources. Due to this, we decided to implement some new techniques based on wind power electricity generation. For that, we are working on some multipurpose scheme for wind power electricity generation. Here we are talking about the main concept of our research paper i.e. "Multipurpose scheme of workshop exhaust system for ventilation and electrical power generation". We divided main concept into two sub concept. First is ventilation and second one is Electricity Generation. We all are aware of workshop roof ventilation system. It provides ventilation to the inner atmosphere of the workshop. Here, exhaust fan is connected with wind turbine. When wind strikes on turbine, it will rotate and exhaust fan will also rotate with turbine. Thus due to the power of wind, this whole ventilation system can work. Here we can apply some new techniques for make this concept more useful. We can develop special generator and generate electric power using wind turbine of workshop roof ventilation system. This generated power can be stored in a storage battery and used for street lighting or workshop lighting. Here we are discuss about second main concept i.e. generation of electrical power using workshop roof ventilation system.

Table – 1
Abbreviation and Acronyms

Term	*Description*	*Term*	*Description*
AC	*Alternating Current*	*SWG*	*Standard Wire Gauge*
DC	*Direct Current*	N_t	*Number of Turns*
EMF	*Electro Motive Force*	*N*	*North Pole*
MMF	*Magneto Motive Force*	*S*	*South Pole*

II. CONSTRUCTION

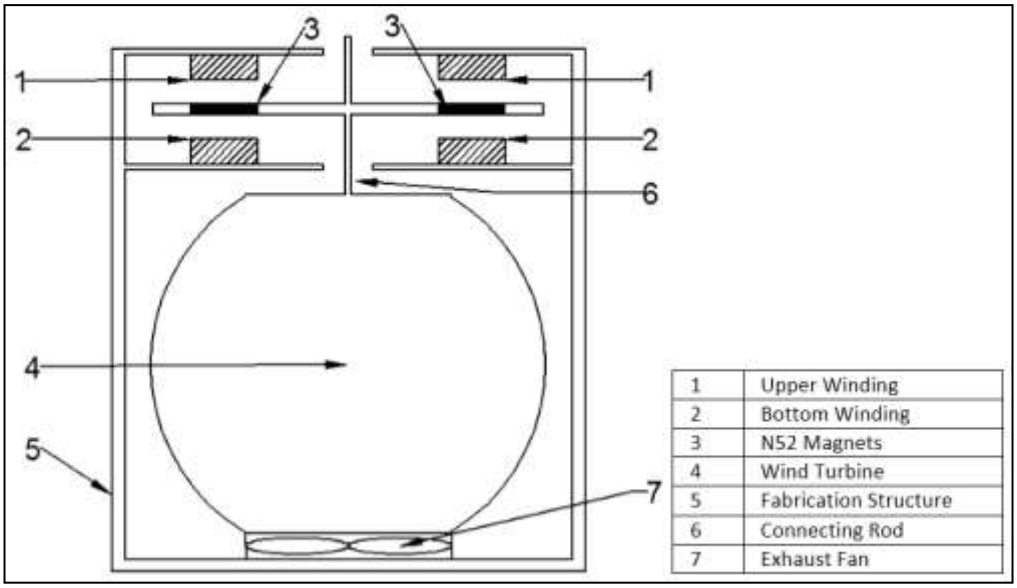

Fig. 1: Construction

For fulfilment of this concept, we have to develop simplest, efficient and economical working model. Figure 1 shows the construction layout of working model. Here we can divide whole model into two sub part i.e. stator part and rotor part. Stator part consist of upper winding and bottom winding. These both windings are placed on the fabrication structure so that wind turbine will not be affected due to the weight of windings and it can be rotate smoothly. Rotor part consist of wind turbine of ventilation system, exhaust fan and magnet disc which is connected to the turbine with connecting rod. Thus magnet disc and exhaust fan can also rotate with the rotation of turbine. Turbine is also mounted on fabrication structure.

III. WORKING

A. Ventilation

First working concept of workshop roof exhaust system is to provide ventilation inside the workshop. We can use motorized exhaust fan which provides ventilation but it will consume electric power. For avoid electricity consumption, workshop roof exhaust system is adopted. Here, exhaust fan is operated with the help of wind power instead of electrical motor. Wind turbine is connected with exhaust fan. Whenever wind strikes on turbine, it will be rotate. With the rotation of wind turbine, exhaust fan is also rotate and sucks hot air or polluted air.

B. Generation of Electrical Power

Second working concept of workshop roof exhaust system is to generate electrical power. Faraday's law of electromagnetic induction is the main working principal. We all are known about faraday's law of electromagnetic induction and it states that "Whenever a conductor is placed in a varying magnetic field or in other case steady magnetic field is cut buy moving conductor, then EMF is induced in conductor and if the conductor make a closed circuit then current flows through it". Here faraday talks about two possibilities i.e. either magnetic field is varying or conductor is moving. In this model, conductor is steady and magnetic field is varying. Now whenever wind strikes on turbine, it will start rotate and due to this, magnetic disc is also rotate with the rotation of wind turbine. Now the magnetic field is varying and according to Faraday's law of electromagnetic induction EMF will induced in winding. This induced EMF is $E = N_t \times (d\O/dt)$ where, N_t is the number of turns, $d\O$ is the rate of change of flux, dt is rate of change of time and E is the induced EMF. We can connect all windings in series or in parallel, according to the requirement. If we need higher voltage then windings should be connected in series and if we need higher current then windings should be connected in parallel. Generated electrical power is AC. We can rectify this AC into DC and after that we can store this generated power into storage battery. This storage power can be used for lighting purpose. Now, during these both working processes, turbine works as exhaust fan and at the same time works as wind turbine for drive the generator. Thus we can say this is a multipurpose scheme for workshop roof ventilation system.

IV. CONSTRUCTION OF MAGNETIC DISC

A. *Arrangement of Magnets*

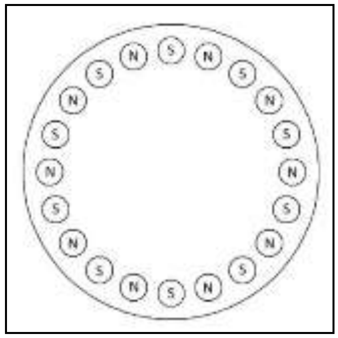

Fig. 2: Arrangement of magnets

Figure 2 represents arrangement of magnets or we can say magnetic poles. Here 20 magnets are used so we can say that 20 number of poles are exist. For generation of electric power, alternating magnetic field is required i.e. N-S-N-S-N. Faraday’s law of electromagnetic induction is only applicable for alternating magnetic field. Numbers of poles must be in even order so that it will be meet to its alternate pole. Major advantage of using higher number of poles is to generate more power in case of lower wind speed. Here, disc type N52 neodymium magnets are place into the holes provided in circular plate. Due to this we can use both sides of magnets. This types of arrangement gives magnetic field on the top of the plate as well as bottom of the plate. Due to this we can place windings at both sides i.e. upper and bottom. With the help of this arrangement we can get maximum utilization of magnets.

B. *Simulation of Magnetic Disc*

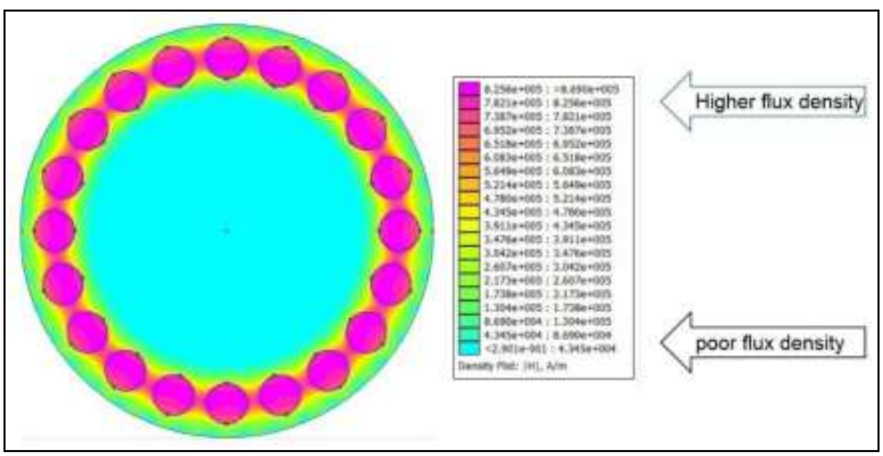

Fig. 3: Simulation of magnetic disc

We have to check that our selected dimensions for the magnet plate will gives satisfactory result or not. For that we have to simulate flux density of magnetic disc. According to the selected dimensions and with the help of FEMM simulation software, we can simulate magnetic disc and find out flux density plot. Figure 3 shows flux density plot of magnetic disc. By visualize different color shades, we can easily observe that which area has higher flux density and which area has poor flux density. Result shows that magnetic field is alternating.

C. *Hardware Implementation*

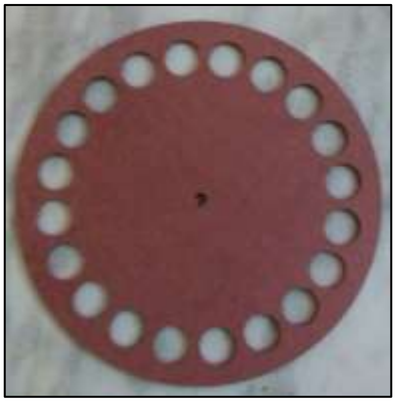
Fig. 4: Magnet disc without magnets

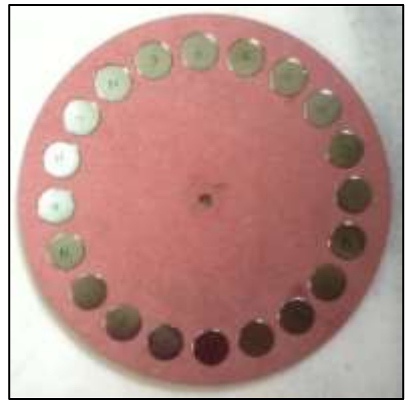
Fig. 5: Magnet disc with magnets

After deciding proper dimensions, we can go for the hardware implementation. Here we are using wooden sheet. A circular piece of wooden plate is cut as per given dimensions. Figure 4 shows the wooden disc as per our design. Disc type N52 neodymium magnets are placed into the holes provided in wooden disc. Figure 5 shows the finalized plate that we are going to use as magnet disc.

V. DESIGN OF WINDING

A. *Calculations for design of winding*

Table – 2
List of Quantity

Symbol	*Description*	*Unit*
A_m	Area of Magnet	m^2 (meter-square)
d_m	Diameter of Magnet	m (meter)
h	Height of magnet	m (meter)
B_r	Residual magnetism	T (tesla)
R	Reluctance	AT/wb (ampere-turns per weber)
AG	Air gap	m (meter)
$\emptyset$	Flux	Wb (weber)
ω	Angular velocity	rad/s (radian per second)
N	Rotor speed	RPM (revolution per minute)
r	Rotor radius	m (meter)
ϑ	Linear velocity	m/s (meter per second)
V	Voltage	V (Volt)
I	Current	A (ampere)
δ	Current density	A/m^2 (ampere per meter)
d_c	Diameter of Conductor	m (meter)
A_c	Area of conductor	m^2 (meter-square)
P	Power	W (watt)
μ_r	Relative permittivity	H/m (henry per meter)
μ_0	Absolute permittivity	H/m (henry per meter)
N_t	Number of turns	-

We have,
d_m = 0.03 m
$A_m = \frac{\pi}{4} d_m = 7.06 \times 10^{-4}$ m^2
h = 0.006 m
For N52 magnets, value of B_r is in the range of (1.42 to 1.47). B_r = 1.45
AG = 5×10^{-3} m
$\mu = \mu r \times \mu r = 4\pi \times 10^{-7}$
r = 0.152 m
Now,
First we need to find MMF and Reluctance for find out Flux.
MMF = Br × h = 8700 AT

Reluctance (R) = $\frac{AG}{\mu \times A_m}$ = 5.6×10^6 AT/wb
Flux = $\frac{MMF}{Reluctance}$ = 1.5×10^{-3} Wb
Now,
For find out Number of turns per coil, we need to find dt i.e. rate of change of time.
Assuming rotor speed is 150 RPM,
Angular velocity (ω) = $\frac{2\pi N}{60}$
= $\frac{2\pi \times 150}{60}$
= 15.70 rad/sec
Linear velocity (ϑ) = $\omega \times r$ = 15.70 × 0.152 = 2.386 m/s
Rate of change of time (dt) = $\frac{2\pi r}{\vartheta}$ = 0.4 sec
Now,
According to faraday's law of electromagnetic induction,
E = $N_t \frac{d\phi}{dt}$
Assuming voltage per coil is 6 V.
$N_t = \frac{6 \times 0.4}{1.5 \times 10^{-3}}$ = 1600
Thus, for generate 6 volt, we required 1600 number of turns per coil with 5 mm of air-gap. But we have to use 1700 number of turns for overload withstand capacity.
Now,
For find out area of conductor, assuming current density as 4 A/m^2 and current capacity is equals to 0.5 A.
$A_c = \frac{I}{\delta}$ = 0.125 mm^2 = 1.25×10^{-7} m^2
Now for round shape conductor,
$A_c = \frac{\pi}{4} d^2$
d = $\sqrt{\frac{4 \times 1.25 \times 10^{-7}}{\pi}}$ = 3.98×10^{-4} m
Now as per SWG, 3.98×10^{-4} m is equals to 28 SWG. So we have to use 28 SWG copper wire for all windings.

B. Hardware Implementation

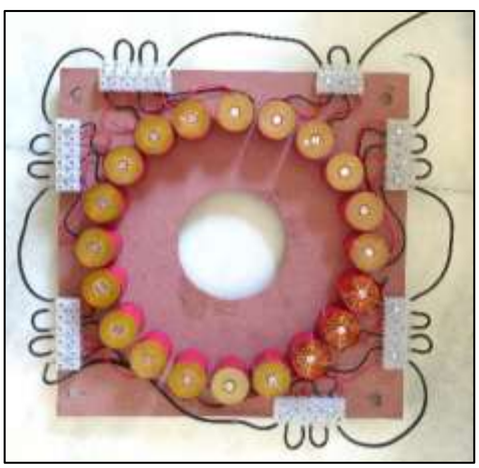

Fig. 6: Upper winding arrangement

Fig. 7: Upper winding arrangement

After getting all useful data from calculation, we are able to implement upper and bottom winding. All windings are placed according to the dimensions of magnet disc. Figure 6 shows the arrangement of upper winding and figure 7 shows the arrangement of bottom winding. Connectors are used for getting different winding connections.

VI. WINDING CONNECTIONS

A. *Case-1: All windings connected in series*

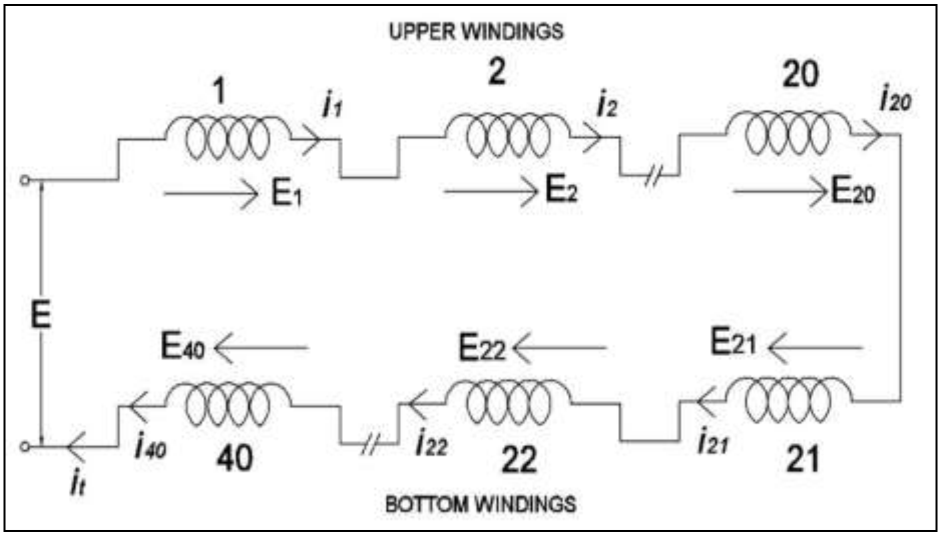

Fig. 8: Series Connection of Upper and Bottom Winding

$$E = E_1 + E_2 + E_3 + \ldots\ldots\ldots\ldots E_{40}$$
$$i_t = i_1 = i_2 = i_3 = \ldots\ldots\ldots\ldots i_{40}$$

In series connection, there will be addition of voltage sources and current sources remains same. This combination gives maximum or full voltage. We can use this combination where requirement of voltage is higher.

B. *Case-2: All windings connected in parallel*

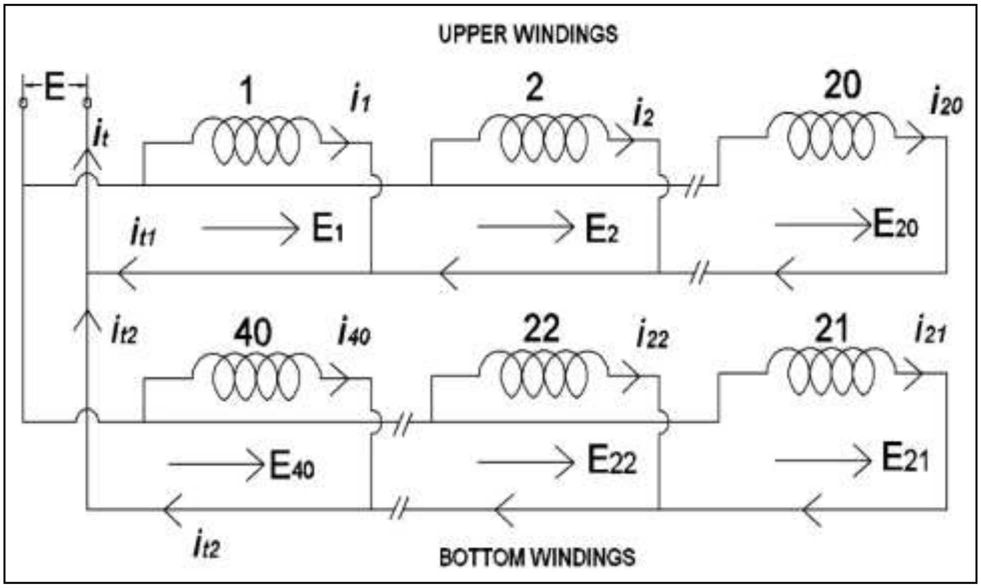

Fig. 9: Parallel Connection of Upper and Bottom Winding

$$E = E_1 = E_2 = E_3 = \ldots\ldots\ldots\ldots E_{40}$$
$$i_t = i_1 + i_2 + i_3 + \ldots\ldots\ldots\ldots i_{40}$$

In parallel connection, there will be addition of current sources and voltage sources remains same. This combination gives maximum or full current. We can use this combination where requirement of current is higher.

C. *Case-3: series combination of parallel connected windings*

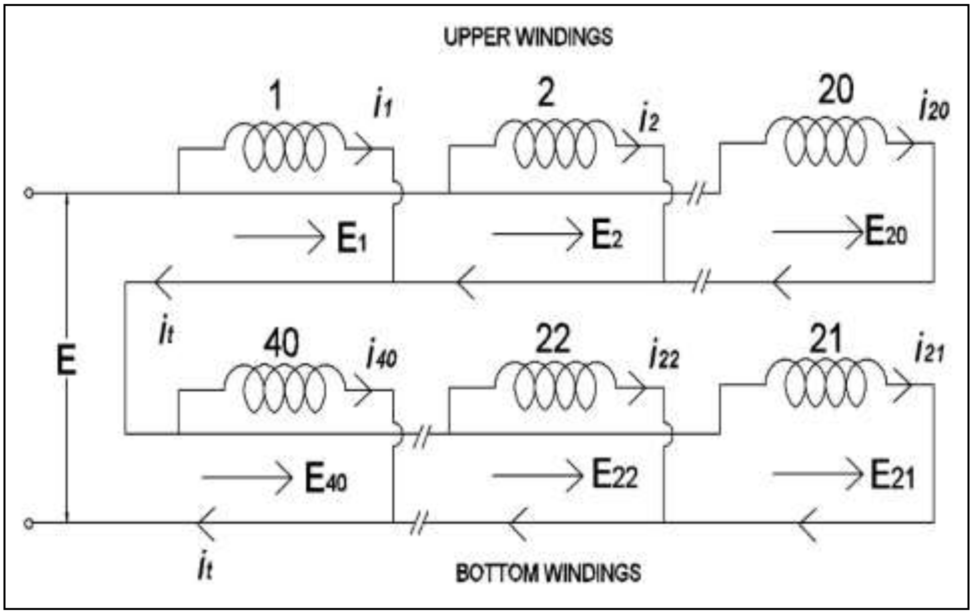

Fig. 10: Series Combination of Parallel Connected Windings

$$E = (E_1 = E_2 = E_3 = \dots\dots\dots\dots E_{20}) + (E_{21} = E_{22} = E_{23} = \dots\dots\dots\dots E_{40})$$
$$i_t = (i_1 + i_2 + i_3 + \dots\dots\dots\dots i_{20}) = (i_{21} + i_{22} + i_{23} + \dots\dots\dots\dots i_{40})$$

This combination is not useful because neither it will give maximum voltage nor maximum current. Note that for parallel connections, we need to use bus bar or current collector which can easily carry maximum current rating.

VII. FINAL ASSEMBLY

Fig. 11: Final assembly

After assemble all different parts, we can get final model as shown in figure 11. Here, wind turbine and magnet disc are rotor part and both upper and bottom windings are stator part. These all parts are mounted on fabricated structure.

VIII. TEST REPORT

A. Observation table for individual windings

Table – 3
Observation table for individual windings

Winding Number	*Voltage (V)*	*SC Current (mA)*	*Winding Number*	*Voltage (V)*	*SC Current (mA)*	*Winding Number*	*Voltage (V)*	*SC Current (mA)*	*Winding Number*	*Voltage (V)*	*SC Current (mA)*
1	*5.3*	*74.5*	*11*	*5.4*	*74.5*	*21*	*5.4*	*74.5*	*31*	*5.4*	*74.4*
2	*5.2*	*74.4*	*12*	*5.2*	*74.6*	*22*	*5.3*	*74.4*	*32*	*5.1*	*74.6*
3	*5.3*	*74.5*	*13*	*5.1*	*74.5*	*23*	*5.4*	*74.5*	*33*	*5.5*	*74.5*
4	*5.4*	*74.3*	*14*	*5.3*	*74.4*	*24*	*5.2*	*74.3*	*34*	*5.2*	*74.5*
5	*5.2*	*74.5*	*15*	*5.4*	*74.5*	*25*	*5.3*	*74.6*	*35*	*5.1*	*74.4*
6	*5.1*	*74.2*	*16*	*5.1*	*74.3*	*26*	*5.2*	*74.5*	*36*	*5.5*	*74.5*
7	*5.3*	*74.3*	*17*	*5.4*	*74.5*	*27*	*5.1*	*74.4*	*37*	*5.3*	*74.3*
8	*5.2*	*74.6*	*18*	*5.2*	*74.4*	*28*	*5.3*	*74.3*	*38*	*5.2*	*74.3*
9	*5.5*	*74.4*	*19*	*5.4*	*74.5*	*29*	*5.4*	*74.5*	*39*	*5.1*	*74.6*
10	*5.4*	*74.5*	*20*	*5.3*	*74.3*	*30*	*5.3*	*74.5*	*40*	*5.4*	*74.5*

Table 3 shows voltage and short circuit current for each windings.

B. Observation table for different winding connections and different parameters

Table – 4
Observation table for different winding connections and different parameters

Serial Number	Winding Connections	Number of Poles	Speed (RPM)	Air-Gap (mm)	Voltage (Volts)	SC Current (Amps)	Frequency (Hz)	Generated Power (VA)
1	Case-1	4	50	10	30	0.021	1.6	0.63
2	Case-1	4	50	5	38	0.026	1.6	0.98
3	Case-1	4	150	10	37	0.026	5	0.96
4	Case-1	4	150	5	44	0.031	5	1.36
5	Case-1	12	50	10	40	0.029	5	1.16
6	Case-1	12	50	5	49	0.037	5	1.83
7	Case-1	12	150	10	58	0.042	15	2.43
8	Case-1	12	150	5	62	0.048	15	2.97
9	Case-1	20	50	10	96	0.053	8.3	5.08
10	Case-1	20	50	5	107	0.060	8.3	6.42
11	Case-1	20	150	10	163	0.071	25	11.57
12	Case-1	20	150	5	210	0.074	25	15.54
13	Case-2	20	150	5	3.8	2.93	25	11.13
14	Case-3	20	150	5	7.7	1.45	25	11.16

Fig. 12: Current measurement

Fig. 13: Voltage measurement

Figure 12 shows 73.5 mA current reading and figure 13 shows 210V AC voltage reading for Case-1. Table 4 shows different measurements for different winding connections. According to the different readings, we conclude that generated power is depends on air-gap, number of poles and speed i.e. rate of change of flux. We also examine voltage and current relationship for series and parallel connections.

IX. OUTPUT WAVEFORM

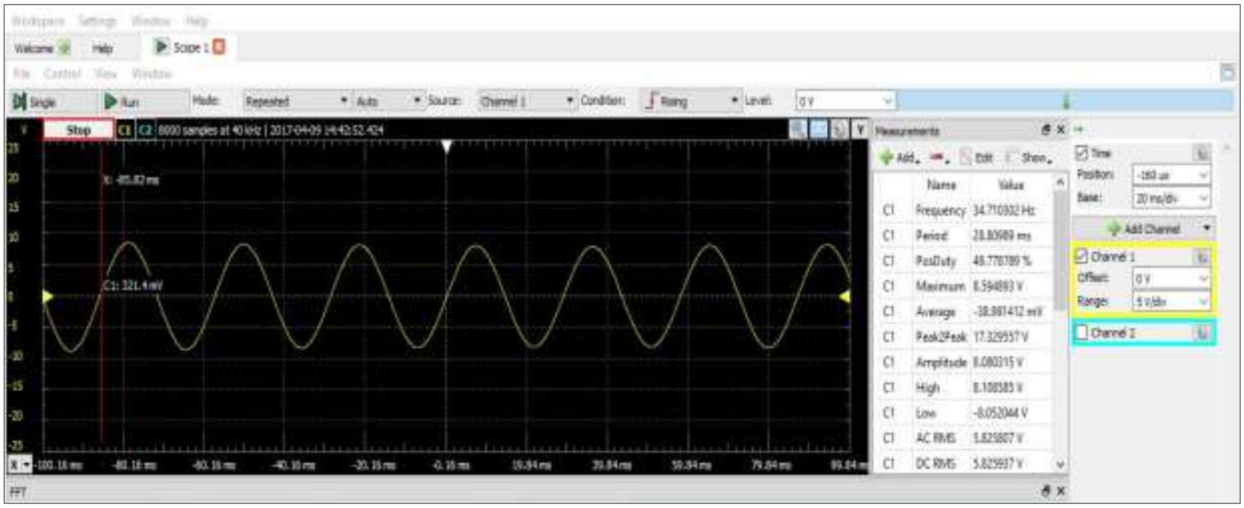

Fig. 15: Output waveform parameters

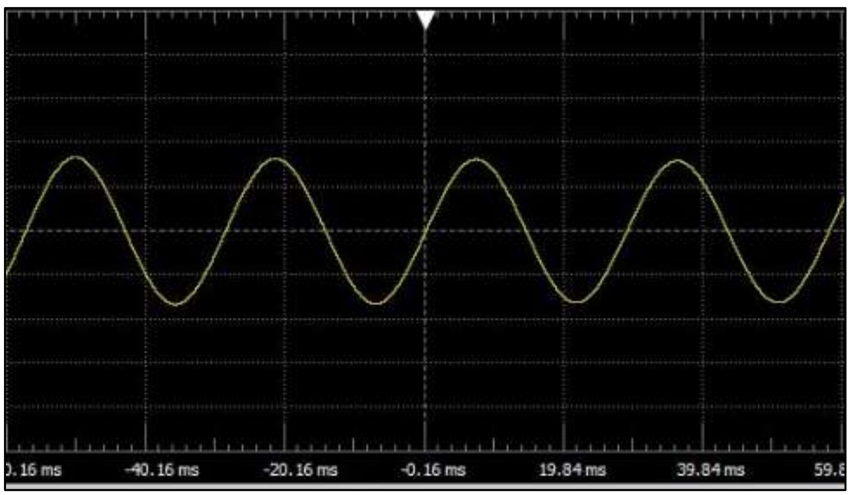

Fig. 16: Pure Sinusoidal waveform

Figure 15 and 16 shows the output waveforms; we get pure sinusoidal waveforms without any harmonics and distortion. We can directly use this AC generated power or we can rectify AC into DC and store into storage battery.

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