ELECTRICITY GENERATION WITH SPEED BREAKER AND APPLICATION OF SMART GRID

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Abstract

Future of luminous and prosperous Pakistan is not far if management fully utilizes conventional and new renewable energy resources. To eliminate the imminent load shedding of 6000MW is the extra-ordinary challenge for Pakistan. Some efforts of AEDB (Alternative Energy Development Board of Pakistan) can nearly fulfill energy supply demand gap in few years by using the wind, solar, biomass and road traffic potential energy.

Major emphasis of this paper is to generate electricity from the tremendous source of road traffic potential energy. Electricity generation from traffic is newest and different idea in this innovative and modern time. A huge amount of potential energy is being wasted in the form of heat and frictional losses daily at toll plazas and everywhere on the busy road.337 KWh to 400 KWh is being wasted every day at a single busy road. This enormous amount of energy can be converted to thousands of KWh electrical units by installing speed breaker based electromechanical system under the road and can share load of national grid. About 90,000 vehicles pass on a single busy road daily so the road traffic is wasting thousands of electrical units daily as well as millions of money.

Keywords: *Renewable Energy, Smart Grid Application, Free Energy, Speed Breaker, Distributed Generation, Electricity Generation.*

Abbreviations: *SPWM: Sinusoidal Pulse Width Modulation*
ISIS: Institute for Software Integrated Systems
CCS: Command and Control System
DSP: Digital Signal Processing
ETAP: Electrical Transient Analysis Program

I. Introduction

After studying research literature, I came to know that early designs of power generation by road traffic were not perfect. They produced very less power only about 50 to 250 watts. My design is totally different. A single unit based on efficient crank shaft mechanism can produce 1508W average power or 24KWh units approximately in 16h of the day at Islamabad toll plaza. If parallel speed breakers are installed at the Islamabad toll plaza, sufficient energy can be stored in the battery bank by rectifying the generated AC [1]. True sine wave three phase SPWM (Sinusoidal Pulse Width Modulation) inverter is designed to convert DC into constant AC 440V and 50Hz. Three phase power transformer 440V/11KV can transmit power towards the smart micro grid as shown in the Figure [1].

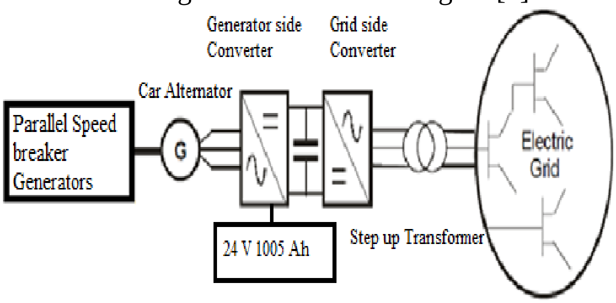


Fig-1 Schematic illustration of the system [1]

II. Scope Of The Paper

Electricity generation from road traffic is cheapest renewable energy resource now a day that can be utilized for transmitting generated electrical power to the local smart grid. In 2012 Pakistan Electric power consumption kWh per capita was 468.91 kgoe/annum (1000Kgoe = 42GJ), in 2009 it was 449.32 kgoe/annum and in 2003 it was 487.3 kgoe/annum (Kilograms of Oil Equivalent per annum) published in

World Bank fact book report 2012 [9]. It is absolutely very less when compared with the average ratings. Pakistan is the importer of energy in this regard. Renewable energy is clean and hundred percent free. Energy utilization from renewable energy resources contribute to the development and prosperity of the country. There are numerous merits of the project when we compare it with the present power situation in Pakistan [10].

Where:

- 1000 kgoe = 42 GJ
- Electric power per capita [in kWh/year] = (1 GJ/a=31.7 W)*(8.766)
- Electric power per capita [in watt] = Total population electricity consumption [in MW·h/yr] *114.077116 /population
- Megawatt hours per year can be written as Watt: 1MW·h/yr = 1000000Wh/(365.25*24)h =114.077116W

III. Methodology

A 3D model is designed according to the laws of physics. In order to generate electricity from traffic potential energy and interconnect it to the smart grid, power equipment and mechanical parts are assembled to make the complete system. Detailed description of the system parts is shown in the 3D AutoCAD model. It is noted that the depth of the infrastructure is set to minimal level that is only 90 cm.

Input kinetic energy of the vehicles is harvested by the speed breaker ramp arrangement making angle of 45 degree installed on the road that transfers input mechanical power to the large sprocket by crankshaft attached with ramp via frictionless bolts on both ends. Rectilinear motion of the crank shaft is converted to rotational motion by large sprocket which is synchronous with the ramp rotation for 45 degree because width of the ramp and radius of the large sprocket are the same. When a tire of vehicle strikes the ramp, it pushes downward from the top side. A gear system, flywheel, special ball bearing of cycle hub and large sprocket are placed on a common hub or center axis.

Large pulley of the gear is coupled with the small pulley of alternator with a belt to increase rpm of variable speed DC generators shown in 3D view of the model. Gear ratio is 9.3 to get 1250 rpm of 24 volt 1500 Watt DC generator that also give output on 800 rpm [3]. Car alternator is used in this project to manage variable speed and give maximum output power.

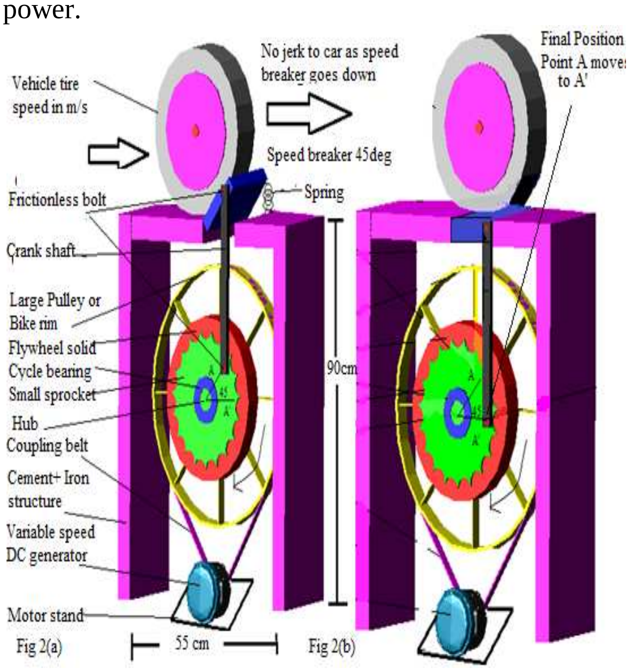


Fig-2 In 2(a) 3D Modeling and parts assembling of speed breaker shown, in 2(b) point A moves to final position A'

Due to variable speed of the AC generator fluctuating voltage and frequency will produce so we need to rectify the output. Rectifier, charge controller and voltage regulator used to charge a battery bank of 24V 1005 Ah.

A single speed breaker unit can fully charge this battery bank in only one hour if it is installed at the toll plaza of Islamabad motorway interchange. True sine wave 3 phase SPWM (Sinusoidal Pulse Width Modulation) inverter converts 24V DC to a constant 440V AC output at 50 hertz frequency, that is used for single and three phase AC loads when transmitted to smart micro grid [2]. This sufficient power can be used for multiple purposes like road lights, signals, toll booth computers, cameras, servers, fans and nearby consumers [4].

IV. Block diagram

Complete project is initially divided to subprojects. Steps towards project completion are presented in the block diagram to get expected results. Each sub block is designed with description.

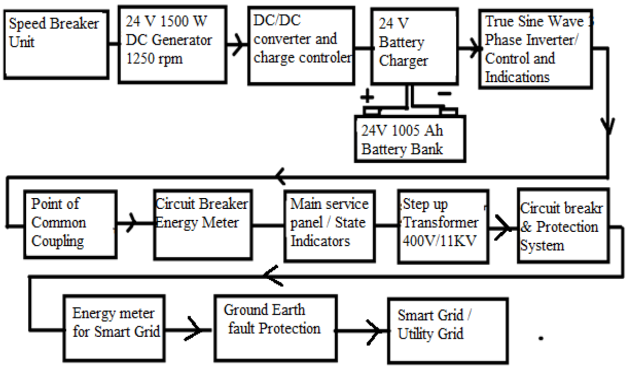


Fig-3 Block diagram of electricity generating speed breaker system and smart grid connection

V. Input Mechanical Power Calculation

Mathematical parameters and relations are defined here for hardware designing, power, torque, force and rpm calculations.

Let a car with mass 1600kg with velocity u1 10 km/h or 2.77m/s collide with speed breaker having velocity u2 zero.

Mass of car (Approximate) = 1600 Kg
Mass on one wheel = 400 Kg
Ramp angle from ground = 45 deg
Ramp width=Large sprocket radius = 12.7 cm
Circumference of large sprocket = 79.8 cm
Input Force by vehicle weight= F = mg
= 400*9.81= 3924 N
Acting force is horizontal component = F*Cos θ
= 3924 Cos 45 = 2775 N
Time in which small sprocket turns to 0 degree from 45 degree = t
Car speed = 2.77 m/s
Arc distance 9.98 cm will be covered in = t
= 1 /2.77*0.0998 = 0.036 s
Work done by the vehicle force = F*d
=2775*0.0998= 276.945J
Power theft by speed breaker from vehicle potential energy= work done / time taken
= 276.945 / 0.036
= 7693 Watts

VI. Output Power Calculation

Mechanical losses like bearing friction, belt pulley friction, windage and slip rings are about 30% approximately due to a smart design.

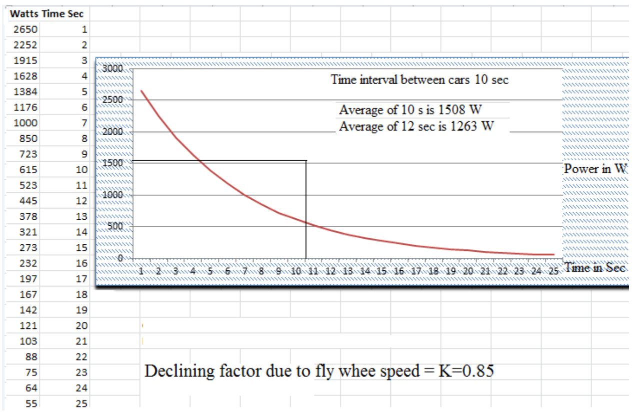
Power transmitted to DC generator= Pin* 0.7
= 5385 W

A 5 KW generator cannot be used because it requires heavy torque to rotate and output response become highly nonlinear in only 5 seconds so we cannot utilize maximum output power due to high inertia of the rotor. Electrical losses are due to the voltage regulator circuit, rectifier, filter, 24 V batteries and inverter circuit. 50 percent electrical power lost generated by car alternator due to variable rpm or very low DC voltage below the rated rpm. So we select the 24V 1250 rpm1500 Watt DC generator for utilizing maximum power.

Maximum o/p electrical power = 5385*0.5
= 2692W
Width of speed breaker = 12.7 cm
Car time to cover this distance = (1/2.77)*0.127
= 46 ms

In 46 ms maximum power generated at the output of alternator = 2692 Watts

Due to inertia of the flywheel DC generator stops after time 25 s approximately. Average power 1508W is calculated where the voltage level is within range from 23V to 28V by integrating the exponential function of the graph as shown up to 10 s because mean service time of a car is 10 seconds. Average electrical power of the alternator is$P = \frac{1}{t}\int_0^t P(t)dt$



Watts	Time Sec
2650	1
2252	2
1915	3
1628	4
1384	5
1176	6
1000	7
850	8
723	9
615	10
523	11
445	12
378	13
321	14
273	15
232	16
197	17
167	18
142	19
121	20
103	21
88	22
75	23
64	24
55	25

Fig-4 Output electrical power of alternator vs time due to declining factor K= 0.85.

VII. KWh Calculations

In one minute 6 cars passed on the speed breaker because mean service time of a car is 10 seconds. Average power generated in 10 seconds is 1508 W. After 10 sec next car leaves the toll booth. Same mechanism repeats and power boosts from 615W to

2692W as shown in the graph and system never stops for 16h in the busy toll plazas like Islamabad.

In one hour average energy generated and stored = 1.508 KWh

In 16h energy stored = 1508*16 = 24.128 KWh

Energy generated by 14units = 337 KWh

VIII. Payback time calculation

From the previous result 14 units produce 337 KWh daily, 10,110 KWh in a month and 123 MWh in the year. WAPDA (Water and Power Development Authority) is selling one unit at the rate of Rs-20 for commercial loads approximately. Initial capital cost, operational and maintenance cost of a year for 14 units is Rs-1,381,000 that can be returned in only seven months and after this period monthly saving is Rs-202,200 that is the excellent result of this project.

IX. Simulation and Programming

24V DC is usable for carrying DC loads of the system. For AC loads we need true sine wave inverter for carrying sensitive loads. Simulation of SPWM (Sinusoidal Pulse Width Modulation) inverter is designed to minimize the system cost and achieve true sine wave. Modern circuit designing and programming techniques for inverter minimize the losses and improve the inverter efficiency up to 90 percent from 60 percent. ISIS (Institute for Software Integrated Systems) or Proteus used for circuit designing and CCS (Command and Control System) compiler for C programming. The schematic diagram is explained here [2].

X. Single phase SPWM inverter

Pulse Width Modulation technique is used in induction motors widely to finely control the speed of the motors. A high frequency triangular carrier wave 1 KHz to 15 KHz is modulated with a low frequency reference sine wave to get therequired50 Hz true sine wave output. Point of intersection of both waves decides to on or off pulses duty cycle. Sine weighted switched pulses are produced that are used for operating 2 MOSFET of N-type IRFP150N that are connected with transformer. PIC 16F877A is used for generating a pure sine wave of 50.34 Hz frequency in the output of inverter from the 12V DC. LCD is integrated with the PIC to show the voltages, system status, protection alarms and temperature [2].

In this simulation title of the paper is programmed as shown in the figure 5.

LC filter is designed to mitigate the harmonics and true sine wave of 50 Hz frequency is generated at the output. Triangular and sine waves are compared by the comparator and output waveform generated with chopping pulses. Triangular carrier wave is 1.2 KHz. This is Pulse Width Modulated waveform with variable duty cycle that is maximum at 90 degree and approximately zero at 0 and 180 degree. Sine table is calculated for 180 degree and pin 9 of PIC16F877A is used for output PWM waveform for 10ms. Schematic diagram is shown in the figure 5.

For generating negative half cycle of output waveform this sine table is repeated for next 10ms. At this stage first MOSFET remains off and second MOSFET is on with defined duty cycles. When the first MOSFET is on for 10ms with defined on and off duty cycle second MOSFET remains off. Power transformer of 3 primary input and 2 secondary is selected to step up the voltage to 220V AC.

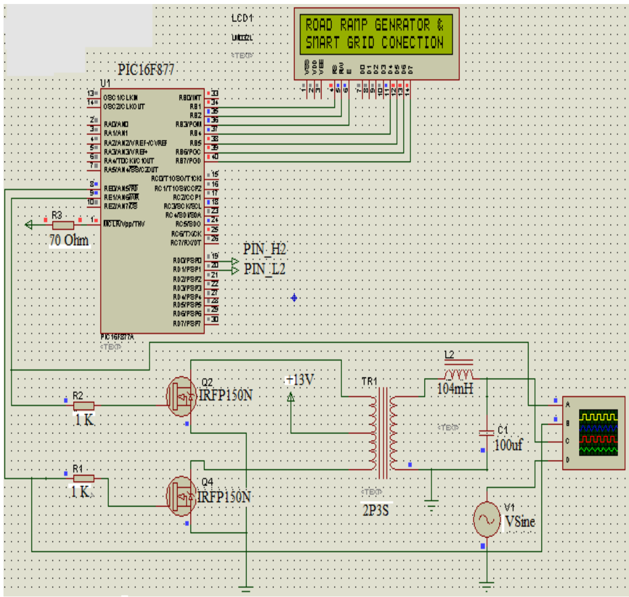


Fig-5 Single phase true sine wave SPWM inverter schematic

PWM and true sine wave is shown in figure 6. Pure sine wave inverters produce very clean waveform that is free from harmonics. Sensitive electronic equipment can be safely run with this high quality pure sine wave inverter like fax machines, digital computer, electronic modules and SMPS [2].

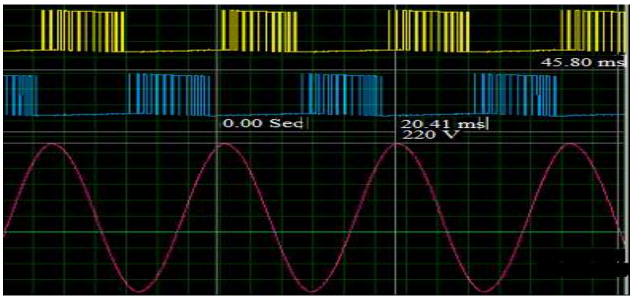


Fig-6 Single phase SPWM inverter output

XI. Simulation of 3-phase SPWM inverter

Computational analysis, circuit designing and programming abilities is the basic requirement for simulating three phase SPWM inverter. Schematic ISIS circuit diagram is shown in the fig-7.Numerical techniques are used by comparing the 12 KHz triangular wave with 50 Hz modulating signal. Each MOSFET is modulated with same triangular carrier waveform but different firing angle of 120 degree [2].

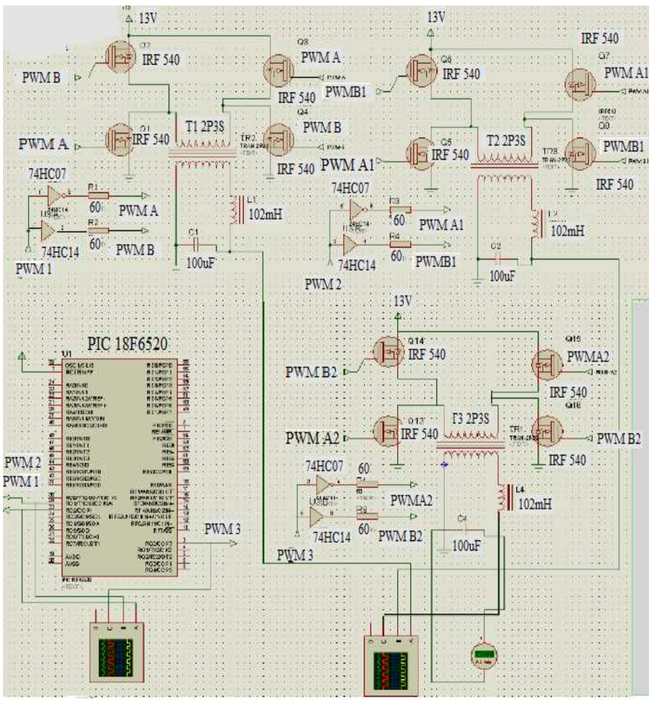


Fig-7 Schematic of 3 phase true sine wave SPWM Inverter by PIC 18F6520 in ISIS

Modulating signal is divided into numerous steps according to the 360 degree angle depends upon the carrier wave frequency. For verification purposes to generate three phase waveform 50 Hz sine wave is divided into 96 steps and calculated sine table for each value. Sine table calculations provide on-off duty cycle to switching MOSFETs.

Finally real time simulation of 3-phase inverter with 120 phase shift is successfully run between three sine waveforms. It is cleared in the figure shown here with red, blue and yellow colors. However, in this black & white printing only different levels of grey can be seen.

It is recommended that specific values are used for different inverter powers.

16 KHz PWM for 1KW inverter

5 KHz PWM for 100KW inverter

1 KHz PWM for 1MW inverter

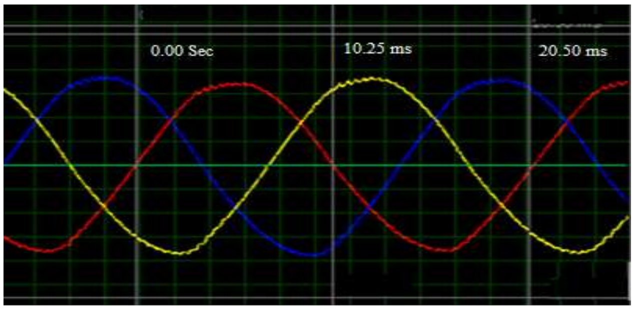


Fig-8 Three phase SPWM inverter output

XII. SPWM Inverter Advantages

Our grid system can import or export power in three phase 11 KV line so 3-phase SPWM inverter is designed. Pure sine wave output with 50 Hz frequency, 120 phase shift is generated as a result that is shown in simulation with different colors. Pure sine wave is free from severe harmonics, distortion, voltage fluctuation, voltage sag and over voltages. It is the efficient method because it requires very less components and reduces the overall cost. Clean sine wave is generated after using LC filters because high switching frequency produces harmonics. MOSFETs can easily handle high switching frequency.

DSP (Digital Signal Processing) based modules in PIC 18F6520 are used for generating three PWM signals that are different in angle. SPWM inverters have 90 percent efficiency which is very high as compared to old inverters that had 60 percent efficiency. This technique also increases the life of batteries as no overloading current is drawn to the circuit. This modern power inverter technique is system efficient and perfect for feeding sensitive loads [5].

XIII. Smart Grid Configuration

Smart grid is a digitally controlled real time network to increase the reliability, sustainability and efficiency of the distribution system. In Fig 9, an example is given where 6 generating units feed 11KV smart grid and load flow analysis is calculated in ETAP (Electrical Transient Analysis Program). 14 speed breaker units generate 337 KWh units in a day and it is transferred to smart grid. A smart grid can also integrate renewable energy resources so electrical output can be connected with the existing distribution network supply of 440V or 11KV supply [11].

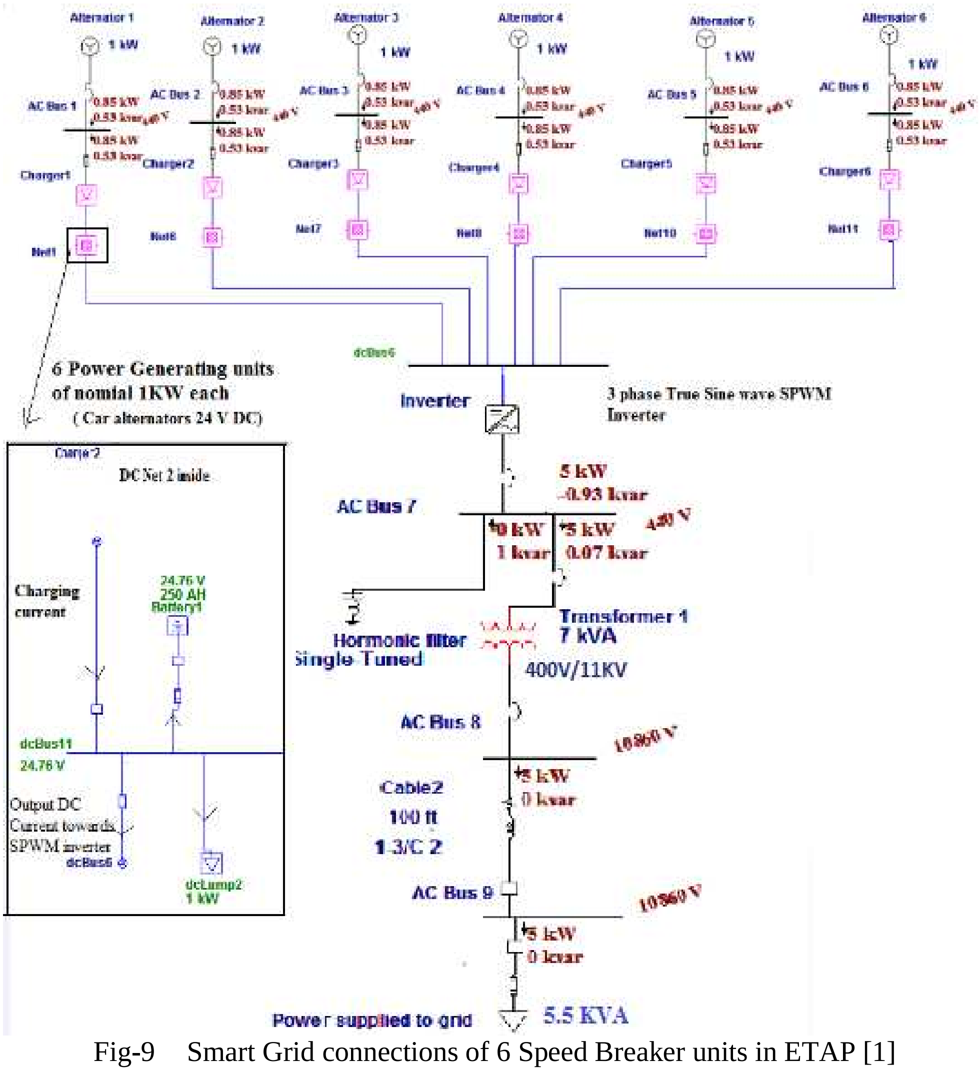


Fig-9 Smart Grid connections of 6 Speed Breaker units in ETAP [1]

Single line diagram in ETAP assure the practical implementation of the proposed load flow solution. DC bus bar, AC bus bar, circuit breaker, transformer, rectifier, inverter and all the appropriate equipment are very important[1], [7].

XIV. Results and Conclusion

For power deficient countries like Pakistan integration of renewable energy power sources with smart grid is highly needed. Renewable energy is totally green and no carbon-di-oxide is produced in this process. About 69120 cars and 90000 vehicles pass from Islamabad toll plaza or Niazi Chowk, Lahore every day in 16h. This equates 337 KWh to 400KWh that is wasting daily. Early ideas of electricity generation from speed breaker generate 25-250 W but this advanced model generates maximum 2.692 KW and average 1.508KW depending upon the net weight of the car.

Single speed breaker unit generates 24 KWh units daily for 16h.Similarly 14 units produce 337 KWh daily, 10110 KWh in a month and 123 MWh in the year. This is similar to 21 KW wind turbine on the road providing constant output. Initial capital cost, operational and maintenance cost of a year for 14 units is Rs-1,381,000. Tariff for commercial users is Rs-20 so capital cost can be returned in only 7 months. After this period monthly saving is Rs-202,200 that is the excellent result of this project.

Three dimensional modeling in AutoCAD helps to understand the practical working of all the mechanical parts. SPWM true sine wave three phase inverter is designed in this project to increase the inverter efficiency 60 to 90 percent to carry sensitive loads.

Generated electricity carries toll booth loads like computers, fans, lights, traffic lights and signal lights. This amount of energy can be used for carrying load of 33 homes with 1KW average load for 24 hours of the day. This energy can also light 240 LED lights of 50 Watt for 12 hours. These bulbs can be of road lights or street lights. Road lights and street lights prevent the people from accident and robbery [8] [10].

XV. Future Work

A clock spring can also be used on the common hub to store the input kinetic energy in the form of potential energy. Constant speed of the AC generator can be achieved by storing vast potential energy in the clock spring. Ac output can be used for definite time depending upon the designing of the new speed breaker model. There will be no need to rectify the AC if clock spring is used.

Capital cost is Rs-65/Watt that is 50 percent lesser than solar system Rs-131/Watt so payback time is very less. Unit has minimal set up and trialing cost. Payback time is only 7 months estimated so AEDB (Alternative energy Development Board of Pakistan) should focus on this project. If AEDB installs 10,000 such speed breaker systems on all toll plazas and different locations of Pakistan, 211 MW can be added on the National grid of Pakistan. This report should be submitted to the research and development department to make a complete feasibility report to practically implement it in our country roads. AEDB, NEPRA and WAPDA should implement this project soon. Multiple stand-alone smart micro grid systems can help to share the load on national grid.

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