COMPRESSED AIR GENERATOR INTEGRATED WITH RENEWABLE ENERGY SOURCE FOR MILITARY APPLICATION

SEMINAR REPORT

Submitted By

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BONAFIDE CERTIFICATE

This is to certify that the seminar report is the bonafide report of the work done by **RESHMA JOLLY (VJC17EE054)** of seventh semester, Electrical and Electronics Engineering in partial fulfillment for the award of the degree of Bachelor of Technology in Electrical and Electronics Engineering of APJ Abdul Kalam Kerala technological university.

Dr. Sony Kurian	**Mr. Jomu Mathew George**
Seminar Cordinator	**Seminar Guide**

Dr . B Aruna
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VISWAJYOTHI COLLEGE OF ENGINEERING AND TECHNOLOGY

VISION

Moulding Engineers par Excellence with Integrity Fairness and Human Values

MISSION

- We commit to develop the institution as a Center of Excellence of International Standards.
- We guide our students in the attainment of intellectual and professional competence for successfully coping with the rapid and challenging advancements in technologies and the ever changing world of business, industry and services
- We help each and every student in their personal growth into mature and responsible individuals.
- We strive to cultivate a sense of social and civic responsibility in our students, thus empowering them to serve the humanity.
- We promise to ensure a free environment where quest for the truth is encouraged.

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VISION

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MISSION

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2. To develop technical and soft skills to cope up with the emerging global scenario.
3. To enhance knowledge by industry and alumni interaction.

PROGRAM OUTCOMES

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design / development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and

write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to ones own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning** : Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM EDUCATIONAL OBJECTIVES

Our Graduates shall have:

1. Foundation in mathematical, analytical and scientific skills to design technically and economically viable engineering solutions.
2. Culture and attitude of team work, to help in upbringing socially committed Entrepreneurs engaged in lifelong learning.
3. Professional communication skills, social values and work ethics.

PROGRAM SPECIFIC OUTCOMES

1. Ability to apply fundamentals of Engineering in analyzing multidisciplinary issues, developing solutions with professional and ethical responsibilities, and promoting conventional and unconventional methods for higher research.
2. Ability to apply Electrical Engineering knowledge to perform Circuit analysis, troubleshoot Electrical machines and optimize Power Systems designs by incorporating analog and digital controls.

ACKNOWLEDGEMENT

I take this opportunity to express my deep sense of gratitude and sincere thanks to all who helped me to complete this seminar successfully. Our first and foremost thanks go to **THE GOD ALMIGHTY** who showered his immense blessings on my effort.

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ABSTRACT

This seminar presents the design and construction of a compressed air storage system integrated with solar energy for Military application. It is a low cost portable system for renewable application. The design is fabricated using the use of commercially easily available components. The study helps in building a solar powered air compressed storage system integrated with an air motor and an alternator to store solar power and use the stored power whenever the need arises. The India Army is looking forward for a durable energy source in high altitudes to enhance living conditions. The overall efficiency of the compressed air storage system integrated with solar power is said to be 53.7%.

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CAES : COMPRESSED AIR ENERGY STORAGE

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CHAPTER 1

INTRODUCTION

In recent years, there are many energy harvesting approaches have been proposed using renewable energy that aims in technological advancements and potential reduction in the system cost by reducing the use of fossil fuels. These include wind turbines, solar power panels, bio gas, large dish photovoltaic technologies. Wind and solar energy sources will be benefited from energy storage as a backup for intermittent load demand. They become more important due to the rising cost and diminishing fossil fuels. The compressed air energy storage (CAES) provides a backup storage for solar and wind energy generation systems. The CAES can store large quantities of energy for long period of time at a very low cost. The major challenge involved in this technology is the need to efficiently convert the compressed air energy into electrical energy. CAES is a technique of storing energy as the potential energy in the form of compressed gas. It refers to air pumped into large storage tanks or naturally occurring underground formations. When energy is available, it is used to run air compressors which pump air into the storage tanks and during the need for electricity, it is expanded through conventional gas turbine expanders. Major challenges involved in this system are its conversion efficiency and lack of storage sites for its integration with renewable energy sources. India is one of the countries with largest production of energy from renewable sources.

CHAPTER 2
LITERATURE REVIEW

2.1) H. Zhao, Q. Wu, S.Hu, H. Xu, CN Rasmussen, **"Review of energy storage system for wind power integration support,"** Applied Energy, vol. 137, 2015, pp.545-553.

Energy storages are emerging as a predominant sector for renewable energy applications. This paper focuses on a feasibility study to integrate battery energy storage with a hybrid wind-solar grid-connected power system to effectively dispatch wind power by incorporating peak shaving and ramp rate limiting. The sizing methodology is optimized using bat optimization algorithm to minimize the cost of investment and losses incurred by the system in form of load shedding and wind curtailment.

2.2) M. Yekini Suberu, M. Wazir Mustafa, N. Bashir, **"Energy storage systems for renewable energy power sector integration and mitigation of intermittency,"** Renewable and Sustainable Energy Reviews. Vol. 35. 2014. Pp. 499-514.

The electric power sector is looking forward towards increasing the bent for availability, reliability and security of energy supply to consumers. This pursuit has vehemently increased the intention for integrating renewable energy (RE) into the electricity sector as a strategy to curb the problem of energy deficiency especially in isolated off-grid settlements.

2.3) **Growth of Electricity Sector in India from 1947-2017**, Ministry of Power, Central Electricity Authority, Government of India, New Delhi, May 2017.

Power Sector in India has grown significantly since independence, both in the installed electricity generating capacity and transmission & distribution (T&D) system. The total power generating capacity of (utilities & non utilities) has increased from a peak 1362 MW in 1947 to about 377 GW at the end of March, 2017.

CHAPTER 3
THEORY AND DESIGN OF CAES

Compressed Air Energy Storage (CAES) is the term given to the technique of storing energy as the potential energy of a compressed gas. It refers to the air pumped into large storage tanks or naturally occurring underground formations. The primary advantage of CAES is achieved when coupled with an intermittent source such as solar energy. The design is divided into three basic sections based on the systems of energy conversion.

i. Conversion of solar energy into electrical energy and then storage of this energy in battery/ultra-capacitors.
ii. Conversion of electrical energy into potential energy of compressed air with the help of an air compressor and then storage of this energy in an air tank.
iii. Conversion of potential energy of compressed air into electrical energy by use of a dynamo/alternator which is coupled with an air motor.

3.1) Solar Energy to Electrical Energy

A solar panel with output rating of 300 watts per panel is used under rated conditions of incident solar radiation and the rated output is given as,

$$E = A \times r \times H \times PR$$

E = Energy (kWh)
A = Total solar panel Area (m^2)
r = solar panel yield or efficiency (%)
H = Annual average solar radiation on tilted panels without shades on the panel
PR = Performance ratio

The output from the solar panel is used to charge the battery and thus solar energy is stored into batteries. The battery charging time can be given by the formula

Charge time (hrs) = (Ampere hours utilized x 1.15)/Charge rate from the solar output.

3.2)Conversion of stored electrical energy to compressed air

In this stage, the stored electrical energy is converted into potential energy of compressed air. The compressor runs using power input from inverter connected to the charged battery/ultra-capacitor or directly from solar panel. This stage involves two basic calculations.

(a) The compressor run time depends upon the output power of the inverter, power requirement of compressor and the capacity of the storage tank and the volumetric flow of air in the tank. The following assumptions are done for simplified calculation.

(i) The compression process is isothermal as temp rise due to compression is neglected.

(ii) The power factor of compressor is **p**.

(iii) Efficiency of compressor is **ŋ**.

(b) The time required to fill the tank to full capacity at rated pressure is given by,

T1 = V1 /v

where, V1 = volume of inlet air

and ν = volumetric flow of air at inlet.

V1=(V2 x P2) / P1

where, V2 and P2 are volume and pressure inside the tank

and P1 = inlet pressure (atmospheric pressure)

The max time for which the battery can run the compressor is given by,

T = (Voltage x Current) x Power factor / (746 x compressor power in hp)

3.3)Conversion of Potential energy to Electrical energy

The last stage of converting potential energy to electrical energy is further subdivided into two steps.

i. Compressed air is applied to an air motor and the volumetric flow of expanding air is passed over the blades of an air turbine/air motor which is converted into a rotary motion.

ii. The output of the motor is connected with a shaft to an alternator which produces electricity as per the rpm of air motor with an assumption of 100% mechanical efficiency between the air motor and the alternator.

CHAPTER 4
CONSTRUCTION OF CAES

The incident solar power on the solar panel is converted into electrical energy due to PV emission caused in accordance with the “photovoltaic effect”. The electric energy produced is in form of direct current which is stored into a battery. The stored energy of the battery is used to run an air compressor by first converting the DC to AC using an inverter and then using the AC power to run the compressor. The compressed air generated by the compressor is stored into the storage tank. As and when the electricity requirement arises, the compressed air stored in the tank is expanded over the blades of an air turbine to run it. The rotary motion so generated is used to run a dynamo/alternator.

The dynamo/alternator produces electrical power that can be used as per load requirements and the output parameters of the generator. The output efficiency of the system can also be augmented with a heat exchanger which heats the expanding air from storage tank using conventional fuel or using the stored heat from the compressed air during compression phase. The addition though increases the efficiency of system but also increases the complexity and the cost of project. Experiments are conducted using available resources and the stages are found to produce an output of 300 to 400 watts for about 5 minutes.

CHAPTER 5
PROPOSED SYSTEM DESIGN

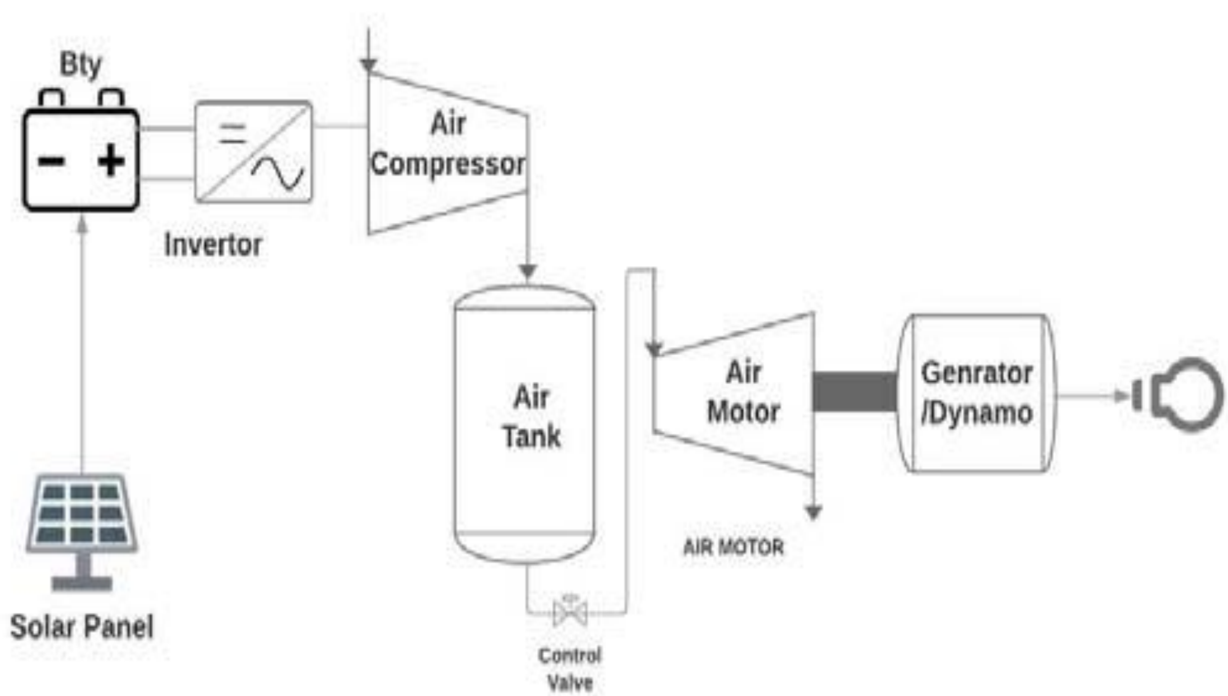

FIG 5.0 : Block diagram of the system

FIG 5.1 : Real time model of the proposed CAES system

CHAPTER 6
RENEWABLE ENERGY SOURCES IN INDIA

	With 0% Energy Price Rise			With 3% Energy Price Rise		
Year	Gross Generation (in Bkwh)	Per Capita Gross Generation	Installed Capacity Requirement (MW)	Gross Generation (in Bkwh)	Per Capita Gross Generation	Installed Capacity Requirement (MW)
2009	979.87	811.33	186429	979.87	811.33	186429
2021	1537.28	1096.58	292481	1356.25	967.45	258038
2031	2577.99	1679	490485	2057.70	1340.15	391495

TABLE 6.0: Renewable energy source and India's future.

CHAPTER 7
RESULTS

Necessary assumptions have been made and the calculations are performed for every energy conversion stage to estimate the final output power and overall efficiency of the prototype model for portable system.

First Stage: Solar power to battery charging is assumed that the efficiency of charger is 100% and it gives a sustained output of 300 watts. Also, it is assumed that battery requires 1.15 times of rated energy for full charging. The time taken to charge the battery of rating 12V/150AH is given as,

Tc Charging time (hrs) = (AH utilized x 1.15) / Charge rate

Tc = (12 x 150 x 1.15) /300 = 6.8 hrs

Total energy stored in battery = 12 x 150 = 1800 VAH

Second Stage: DC to AC conversion using invertor assuming efficiency of 0.9 and power factor of 0.8, the output energy available from the invertor is

Total inverter output = 1800 x 0.8 x 0.9 = 1296 Watt-hr.

Third Stage: The above output can run the 1 hp compressor whose overall efficiency is 0.8 for time Tc is given as,

Tc = (Inverter output / compressor rating) hrs

Tc = 1296/ 746 =1.74 hrs

The power output to run the compressor for 1 *hr* (746 / 0.8) x 0.9 x 0.8 = 671 watt-hr

The minimum run time Tr required for the compressor with the given parameters and assuming the process is isothermal as,

Tr = V1 / FAD of compressor

Tr = 8.23 minutes

But, the actual process is isentropic and the buildup pressure in the tank opposes the air flow and the actual Tr will be
between 12 –15 min. The power input to run the compressor for a duration of 12 min is 134 Watts (671x12/60).

Fourth Stage: The compressed air in turn runs the air motor

Fourth Stage : The compressed air in turn runs the air motor at rated 800 rpm for 4 minutes with a 200-litre air tank.

The total work output at motor = motor rated power x time

= (1300/60) x4 = 86.7 Watt-hr.

Fifth Stage*:* The air motor in turn run the alternator to produce an output for 4 min with the given 200-litre air tank capacity.

The work of alternator (12 V, 90 A) = ((12x90x0.9) / 60) x 4 = 64.8 Watt-hr.

Total efficiency of the CAES system = Alternator output/Electrical input to the compressor

= (64.8 / 134) x100=

53.7% .

CHAPTER 8
CONCLUSION

The compressed air energy storage system integrated with solar power was studied and presented as a low-cost system design and fabrication using commercially available components. The design is portable for military application and can be used with solar and wind energy sources. The designed unit had achieved an overall efficiency of 53.7%. This paper presents a cascaded tank capacity of 200 liter using a 160 liter and 40 liter tanks connected together. This method can be used to build large tank capacity by placing one over the other for limited area application.

CHAPTER 9
FUTURE SCOPE

The efficiency of the system can be improved by keeping the container at elevated temperature. Secondly, blow type airbags can be tried for easy portability to remote site for military application.

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III. M. Yekini Suberu, M. Wazir Mustafa, N. Bashir, “Energy storage systems for renewable energy power sector integration and mitigation of intermittency,” *Renewable and Sustainable Energy Reviews*, vol. 35,2014, pp. 499-514.

IV. Growth of Electricity Sector in India from 1947-2017, Ministry of Power, Central Electricity Authority, Government of India, New Delhi, May 2017.