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Design and Development of Renewable Energy Battery Storage System

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Abstract: Storage alternatives are becoming more critical as energy systems become more decentralised, specialised, and dependent on sporadic clean sources. This is because stable grids and supplies depend on reliable storage. Compressed Air Energy Storage is one technique that is still not being fully utilised. The development of renewable energy over the past 20 years has not been a complete success for grid operators. Decentralized assets that deliver power into the grid at unpredictable intervals are replacing the outdated model of energy production in massive, centralised power plants. The need for effective, sustainable, and affordable energy storage technologies is mostly motivated by the ensuing instability and grid management difficulties. Compressed air-based electricity storage is one of the technologies whose potential has not yet been fully realized. The idea of compressed air energy storage (CAES) is not new. These technologies are currently receiving increased attention due to the need to stabilize the grid, and are moving towards commercial viability thanks to market forces and carbon emission regulation.
Keywords: Compressed Air Energy Storage, storage alternative, renewable, sustainable, effective

I. INTRODUCTION

Electrical Energy Storage (EES) is a fashion that transforms electrical energy from a power network into a form that may be stored for after conversion back to electrical energy. An approach like this makes it possible to induce electricity during times of low demand, low generation cost, or from intermittent energy sources, and to use it at times of increased demand, increased generation cost, or when no other source of generation is available. The origins of EES can be traced to the turn of the 20th century, when power plants constantly shut down for the night and lead- acid accumulators were used to power the remaining loads on the direct current (DC) networks at that time. Mileage companies gradationally understood the value of the inflexibility that energy storehouse offers in networks, and in 1929 the first central station energy storehouse, a Pumped Hydroelectric storehouse (PHS), was put into operation.

Around the world, further than 128 GW of EES had been installed as of 2011. EES systems is presently passing commodity of a belle epoque due to a number of factors, including changes in the global mileage non-supervisory terrain, an ever- adding reliance on electricity in assiduity, commerce, and the home, problems with power quality and a force, the expansion of renewable energy as a significant new source of electricity force, and all of these factors combined with ever-stricter environmental conditions. These rudiments, along with the prognosticated unit cost diminishments and the fast- accelerating rate of technological progress in numerous of the developing electrical energy storehouse technologies, have led to a largely favourable outlook for their practical uses over the coming several times. For the USA, Europe, and Japan, the prognosticated storehouse position will rise to 10 – 15 of delivery supplies soon.

There are numerous EES technologies, including Flywheel, Capacitor, and Super capacitor, as well as Pumped Hydroelectric storehouse (PHS), Compressed Air Energy Storage System (CAES), Battery, Flow Battery, Energy Cell, and Solar Energy. still, only two EES technology types — PHS and CAES are dependable for energy storehouse on a large scale (over 100 MW in a single unit). The most frequently used PHS.

The introductory idea behind it's to transfer water from a lower force to an elevated force in order to store hydraulic implicit energy. PHS is an established technology with a high energy effectiveness, long storehouse time, big volume, and fairly low capital cost per unit. The lack of suitable locales for one or two heads and two sizable budgets is a significant debit. The other three major constraints on the deployment of PHS are a lengthy lead time (generally 10 times), a high construction cost (generally hundreds to thousands of millions of US bone), and environmental enterprises (similar as clearing trees and foliage from large areas of land before the force is swamped). Due of PHS's limitations, CAES is an charming volition for large- scale energy storehouse. Other than PHS, the only commercially feasible technology that can supply veritably-large system energy storehouse (over 100MW in a single unit) for use in commodity storehouse or other large- scale storehouse is called CAES.

II. CAES TECHNOLOGY ACROSS THE WORLD

The conception of CAES can be dated back to 1949 when Stall Laval filed the first patent of CAES which used an underground grotto to store the compressed air. Its principle is on the base of conventional gas turbine generation. In low demand period, energy is stored by compressing air in an air tight space (generally4.080 MPa) similar as underground storehouse grotto. And the turbine is connected to a creator to produce electricity. A CAES system consists of over- and below- ground corridor that absorb, store, and distribute energy by utilising both man- made technology and natural geological conformations.[7]

1) Japan Chubu design Chubu Electric of Japan is surveying its service home for applicable CAES spots. Chubu is Japan’s third largest electric mileage with 14 thermal and two nuclear power shops that induce 21,380 MWh of electricity annually. Japanese serviceability fetes the value of storing out- peak power in a nation where peak electricity costs can reach$0.53/ kWh.
2) Eskom design Eskom of South Africa has expressed interest in exploring the profitable benefits of CAES in one of its intertwined energy plans.
3) The third marketable CAES is a 2700 MW factory that's planned for construction in the United States at Norton, Ohio developed by Haddington gambles Inc. This 9- unit factory used to compress air up to 10 Mega Pascal in limestone mine pate 670m below ground.
4) Project Markham in Texas This 540 MW designed concertedly by Ridege Energy Services and EI Paso Energy is correspond to four 135 MW CAES units with separate low- and high-pressure contraction trains driven by motor.[8]

III.PROPOSED WORK

The maturity of energy storehouse systems call for changing the useable energy's original condition into bone that's further suited for storehouse. It is also changed back into a usable form when it is ready for operation. Every conversion involves a loss in the effectiveness of the convers process, hence it is important to consider the storehouse system's total turn- around effectiveness when comparing different energy storehouse options. Batteries actually stores energy in a chemical form, but when given a conduit for the energy to flow, the battery will naturally convert the energy to direct current electric power. Any different types of flywheels, compressed air, and pumped hydro systems are exemplifications of mechanical storehouse. According to Willis and Scott (2000), thermal storehouse systems employ energy to heat a liquid to extremely high temperatures, which is also used to toast brume to power a brume turbine creator or a sterling cycle creator. When creators are suitable to produce energy in real time as it's being consumed, energy storehouse systems have always taken a aft seat. Energy storehouse has a delicate time contending due to the high outspoken costs of developing storehouse systems and the expenditure associated with energy losses that do while transferring the energy from one form to another for storehouse.

A CAES (compressed air energy storage) project's technique can change based on the particular objective, specifications, and limitations of the project. However, the following steps can be included in a general methodology for a CAES project:

1) *Feasibility Study:* To ascertain the project's technical and financial viability, a feasibility study is the initial step in any CAES project. The potential site, energy consumption, storage capability, and project costs must all be evaluated.
2) *Site Selection:* The next step is to choose a suitable location for the project after the feasibility study is finished and it is determined that the project is viable. This might entail finding caverns beneath the ground, closed mines, or other places that can house compressed air.
3) *Design and Engineering:* The CAES system's compressors, storage tanks, turbines, and other necessary equipment must now be designed and engineered.
4) *Construction and Installation:* This phase is what follows the completion and approval of the design. This entails constructing the required infrastructure, setting up the necessary hardware, and testing the system.
5) *Commissioning and Testing:* After the system is put in place, it needs to be tested and commissioned to make sure it adheres to design guidelines and performance standards.
6) *Operation and Maintenance:* After the CAES system is installed and put into use, regular maintenance and supervision are necessary to make sure it keeps working correctly and effectively.
7) *Optimisation and Expansion:* It may be able to optimise the CAES system to enhance effectiveness, dependability, and performance as the system is used and data is gathered. It might also be essential to extend the system to accommodate rising energy consumption.

Overall, a CAES project's methodology entails a thorough and iterative procedure that comprises feasibility studies, site selection, design and engineering, construction and installation, commissioning and testing, operation and maintenance, and optimisation and expansion.[11]

A. Component Specification

The list of the components used in the development of the project is as follows

1) DC Compressor (12 v)
2) Solar Panel (80 W)
3) Pressure vessel (3×9 litres
4) Turbowheel
5) Generator
6) LED Strip
7) Non-Return Valve (NRV)
8) Miscellaneous: Air tubes, On-Off Switch

B. Procedure

The solar panel of 80 Watts is selected for this prototype. The energy obtained from the solar radiations through solar panel is used to run the compressor. Since this is a renewable source of energy to run the compressor, it is referred to as renewable energy storage system. The compressed air obtained from the compressor is fed and stored into the pressure vessel designed. The storage of compressed air into the designed pressure vessel is called as the charging process of the mechanical battery energy storage system.

Further, this compressed air stored in pressure vessel is released onto the turbowheel which is enclosed in a closed casing. This closed casing is designed based on the dimensions of the turbowheel used in the prototype. Then the shaft of the turbowheel is connected to the DC dynamo generator to obtain the power output. This power output is the supplied to the LED strip attached to showcase the output of the stored energy. This process of lightening A LED strip is called as discharging process in the mechanical battery system.

This process is thus termed as SCAES (Small scale compressed air energy system).

C. Calculations

Isothermal compressed air energy storage system variable,

Compressed air pressure = 6 bar = 600Kpa Temperature in K = 20+273 = 293K

Free energy in this case is given by

$W = RT\ [\ln Pf/Pi]$

$W = 0.287x293[\ln(600/100)]$ W= 150.67 KJ/Kg.

By ideal gas low,

$Pv = mRT$

$m = PV/RT$

$m = 6\times10^5$ (Pa × (27×10−3m3)/287×293K

m= 0.192 kg

m = 192-gram mass of air stored.

Energy stored in tank = 150.67 KJ/Kg× 0.192kg

= 28.928 KJ

Input power = 28.92 KJ

We obtained the output of 18 watt when performed practically which is considered for further calculations,

P output = 18 watt — 18v dc × 1 amp

P watt = 1000×Ekj/t sec

E(KJ) = 300×18 watt/1000

E(KJ) = 5.4 KJ

Efficiency = power output / power input

= 5.4 / 28.92

= 0.1867

= 18.67 %

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D. Software Analysis

Using the 3D modelling software SolidEdge, the 3D model of a working prototype is created to demonstrate the arrangements of the components used in designing a mechanical battery. The 3D model of a prototype built is shown in the images attached below:

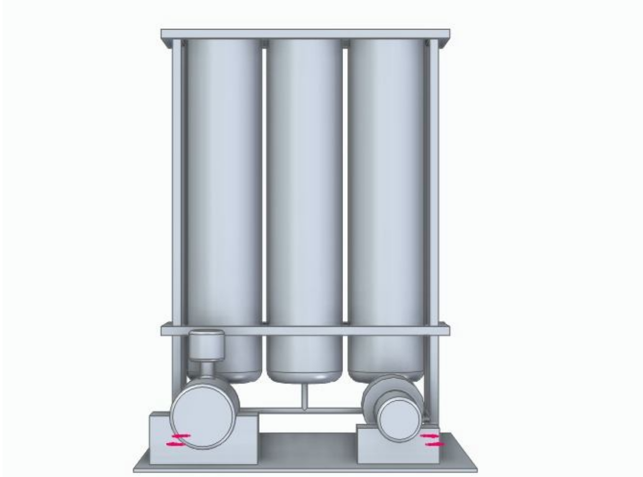

Fig 1. Front view of the model design

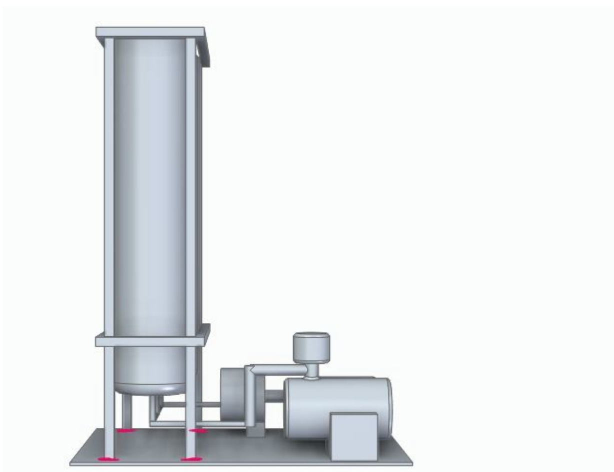

Fig 2. Side view of the model design

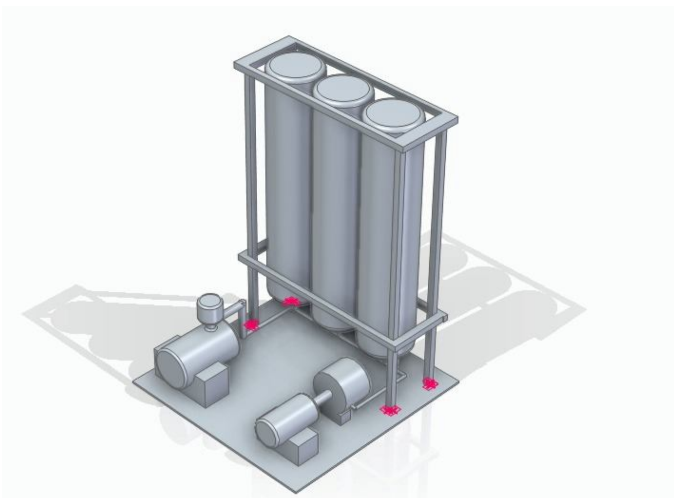

Fig 3. Isometric view of the model design

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Using this software, CFD analyses of colourful stress situations and haste graphs of turbo bus used as turbines are performed. Software like CREO and ANSYS can be used to conduct the study. The impeller is modelled using the CREO software, and analysis is carried out using ANSYS. The impact of temperature, pressure, and convinced stresses on the impeller has been smoothly delved. To explore the colourful stresses, strains, and deportations of the impeller, a structural analysis has been done. According to the findings, the nickel amalgamation revealed advanced rates and is advised for continuing use in the turbocharger impeller. The factual turbocharger from a diesel machine was used to determine the size of the impeller employed in this inquiry. The confines were measured, and using CREO software, they were utilised to produce a 3D model. The impeller model that was put into ANSYS is displayed.

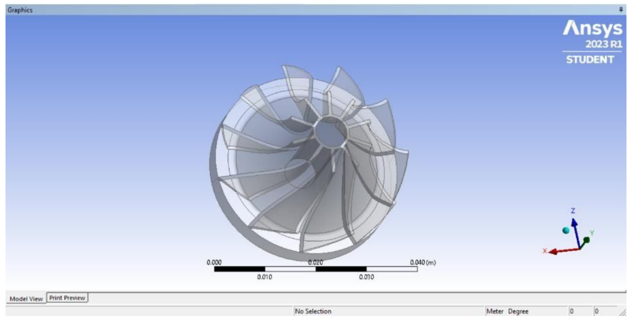

Fig 4. Import the turbowheel design in Ansys

ANSYS was used to perform the analysis for the turbocharger impeller. The model of the impeller was made using CREO for the logical phase, and the lines were saved in STEP format and loaded into ANSYS. According to the literature review, nickel amalgamation achieves the least quantum of stress and distortion. also, for the material Nickel amalgamation, the total thermal flux convinced on the impeller was low. thus, if nickel amalgamation is used, the impeller could repel further pressure and temperature. We thus come to conclusion that nickel amalgamation is the stylish material for the turbocharger's impeller. Diesel machines of this type heavily calculate on turbochargers to ameliorate overall effectiveness. Effective use of the turbocharger greatly lowers the machine's specific energy consumption.

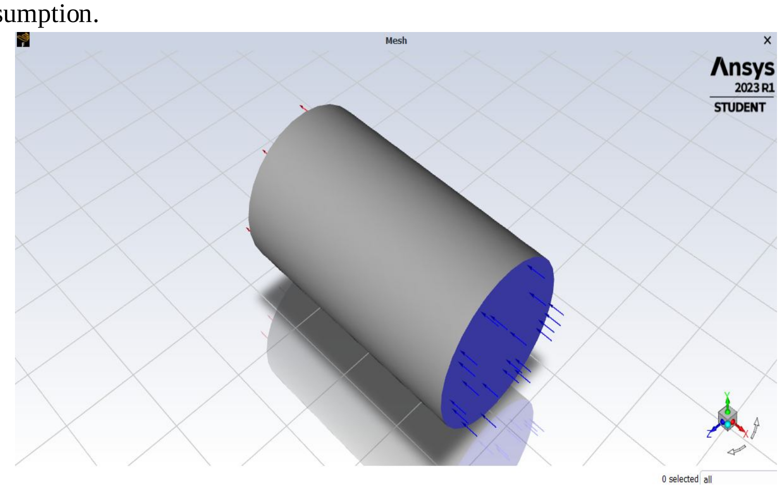

Fig 5. Boundary conditions applied

When working, the impeller's material should be suitable to repel the high pressure of incoming compressed air. The performance of the impeller used in diesel machines was being tested using a variety of accoutrements. Multitudinous experimenters have also experimented with nickel amalgamation and titanium material in an trouble to use it as the impeller for turbochargers. The experimenters also created and experimented with a variety of compound accoutrements to meet the precise rates demanded by the impeller. The near net form machining, which is an precious operation, presents a challenge in converting a compound material for use in the fabrication of impellers. thus, numerous experimenters use the being blends by perfecting their parcels.

Using CREO software, the impeller's 3D model was created. In ANSYS software, the analysis was carried out by roughly bluffing the corresponding material parcels using the models that had been created. The primary stress and strain conditions as well as the characteristics of the heat flux were completely examined.

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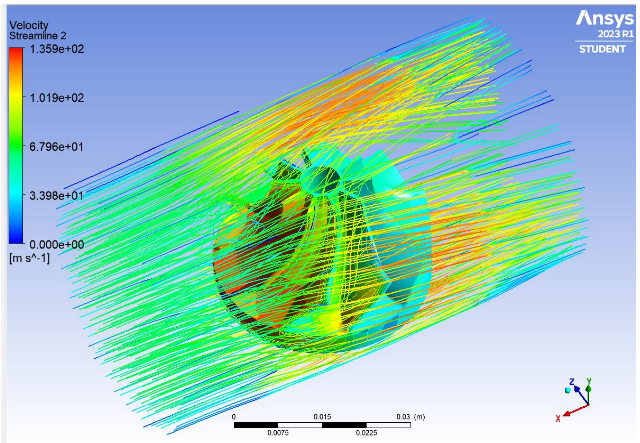

Fig 6. Velocity streamline

E. Results

The results obtained while working of this prototype are as follows:

1) Charging time

For 3 bar pressure - 10 min for 6 bar pressure - 30 minutes

2) Discharging time and output power

At 3 bar - 90 seconds Output voltage - 8-14volts

At 6 bar regulated output - upto 300 seconds at output voltage upto 18v DC

F. Discussion

The thing of this exploration was to determine whether SCAES (using out- the- shelf outfit) might give a workable cover for the requirements of energy storehouse in a menage setting. SCAES technology would significantly reduce the strains on electrical networks and profit those abiding in poor nations or who are unfit to connect to a power grid. also, the heat energy produced by contraction could be captured and used to toast our homes, produce hot water for cuisine, or indeed turn on a light bulb.

G. Efficiency of Compressed Energy Storage System

According to Moskowitz (2010), a compressed air system's overall effectiveness can be as low as 10- 15. All implicit losses that may do from the time a specific volume of air enters the compressor until it's exhausted from the air motor must be taken into account when assessing the system's effectiveness. These losses are attributable to

1) The air entering the compressor, if it's coming from a hotter position. As a result, lower air (weight) is pumped into the cylinder with each stroke, taking further power to compress the same quantum of air in the same quantum of time. By creating suitable arrangements for the air input from the coolest outside point near the compressor structure, this loss can be avoided.
2) To the disunion in compressor together. Generally, this will affect in a power loss of between 15 and 20. Good workmanship can cut it down to roughly 10, but it cannot be fully averted.
3) To number of excrescencies in the compressing cylinders, similar as a lack of free air, a gruelling discharge, poor cooling setups, shy lubrication, etc.
4) Pressure loss in the pipe line from disunion and other factors.
5) The air expanding in the cylinder of the air machine causes disunion and a drop in temperature.
6) To leaks in the air machine, pipe, and compressor (Simons, 1914).

H. Other Alternatives

In the design specification for this discussion one of the issues was to probe other alternatives for the primary energy source or direct drive of the compressor, like using wind turbine, solar thermal etc. The traditional way of exercising wind energy is for a turbine to drive a creator and produce electricity which in turn would power an air compressor.

When using a wind turbine to power an air compressor directly, the air compressor and turbine must be matched so that they run at the same speed range under all wind conditions. This is more complicated than simply producing electricity to run the air compressor. This also brings up the point that multitudinous compressors could operate if the wind turbine was producing power as opposed to using a direct coupling on a single compressor. Hydraulics is a different result that would be far more effective than air but has certain downsides of its own. like having the oil painting at the proper temperature, or the pump's tightly befitting corridor, which increase disunion and make it delicate to turn the motor. Cold oil painting would have a advanced density, which would increase disunion. The size of the receiver demanded to store a sufficient quantum of energy would be the final factor to take into account. Information about solar thermal energy and compressed air is extremely scarce. Nonetheless, the literature did show that solar air exertion is regarded as a thermal storehouse device. But before the refrigerant is fed directly into the compressor, it's hotted using thermal energy. However, the energy would first need to be converted into electricity before it could be used to drive a compressor, If this was intended to directly drive a compressor. This conversion would inescapably affect in some losses. The volume of water inflow per time unit, the perpendicular height that water can be forced to fall (head), and the body of water utilised as storehouse are the three crucial rudiments that determine the generating eventuality at any given point when considering a pumped storehouse hydro as an energy system. In discrepancy to wind and solar energy, which are both generous during famines, the quantum of water stored will shrink and dematerialize, leaving no water available to use as energy to run the compressor. Pumped storehouse hydro systems, like wind turbines, are constantly coupled to creators that give electricity as demanded to power ministry like air compressors. The storehouse of compressed air and the size of receiver needed to store the necessary quantum of energy remain problems with all of these other options. The SCAES system, which serves as the foundation for this exploration, made this veritably clear. Although the size of the receiver will not change by using these other indispensable energy sources, the system's effectiveness may rise. However, farther study would be demanded to see how these options would bear because at advanced pressures, the compressed air's specific power and energy are vastly lesser and further air can be compressed into a receiver, If the SCAES system pressure was increased over 1000 kpa.

IV. CONCLUSION AND FUTURE SCOPE

To summarise, small-scale and renewable energy-based projects can help to address climate change, achieve state energy and climate goals, reduce impacts on land and natural resources, support local economic development, and provide local energy resilience for communities and organisations. Small-scale and renewable energy-based projects can offer specific benefits customised to local and environmental expectations and aims. However, because these projects are so unique, providing a complete assessment of the energy, environmental, economic, and social benefits and challenges of small-scale and renewable energy-based initiatives is difficult. All energy projects include trade-offs, and those trade-offs may change dramatically for small scale and community-based initiatives, but they will also be more adaptable to satisfy environmental concerns and demands. There are other potential benefits for the project that should be considered, in addition to the advantages of clean energy provided by small-scale and renewable projects. These include increasing community energy resilience, enhancing local socioeconomic value, and building a local renewable energy project economy, including infrastructure and employment opportunities. An individual project's value for these special advantages would need to be evaluated on a case-by- case basis within the larger framework of achieving an equitable clean energy transition. Applications for compressed air energy systems (CAES) can be found in a wide range of commercial, residential, and industrial settings. They produce energy by compressing air into a tank or other storage space and then releasing it.
The following are some typical CAES applications:

1) *Power Generation:* By compressing air and storing it in underground caverns, CAES can be utilised to produce power. The compressed air is released when electricity is required in order to power turbines and produce electricity.
2) *Pneumatic Tools:* Air hammers, drills, and grinders are examples of pneumatic tools that are frequently powered by compressed air.
3) *HVAC Systems:* Building HVAC (heating, ventilation, and air conditioning) systems can be powered by CAES. Air handlers, pneumatic dampers, and other HVAC equipment can all be run on compressed air.
4) *Transportation:* Bicycles, scooters, lorries, buses, and other vehicles can all be propelled by compressed air.
5) *Manufacturing:* Pneumatic cylinders, air motors, and air-operated valves are just a few examples of how compressed air is frequently employed in manufacturing operations.
6) *Energy Storage:* Using extra energy to compress air and store it for later use, CAES can also be utilised as a sort of energy storage.

Overall, CAES has a wide range of applications and can be employed in a variety of settings where energy is required.

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