

The Road Map Towards 2020

Eliminating Battery Back-up Power with the Use of Compressed Air

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Abstract: Engineers at PNU Power have harnessed the energy stored in compressed air to provide backup power in high voltage electricity substations. Reduced maintenance costs, elimination of hazardous lead acid batteries, and the need for outside installations were all driving factors for the UK and USA National Grid to look for an alternative to the traditional lead acid battery for backup power. The PnuPower Compressed Air UPS provides a battery free solution to their backup power needs.

compressed air UPS product so it was necessary to design a larger generator to increase the power capability to 3kW for this application. Recent developments have now increased the maximum capacity to 10kW and the product range includes 3, 5 and 10 kW options with the ability to parallel for increased power.

I. INTRODUCTION

Lead acid batteries are the most common form of energy storage for backup power for telecoms, data centers and electricity substations. Batteries for the telecom industry are typically configured for 48Vdc operation, whereas, the data center applications usually require voltages of 450 Vdc or higher. High-voltage substations often use a combination of 110 Vdc and 48 Vdc to back up the control and communication equipment that maintains the high voltage substations in the event that the local grid power were to collapse. Some of the substations use air blast circuit breakers and as such have large reservoirs of compressed air and an air ring main to supply the equipment distributed throughout the station. Harnessing this source of energy and converting it into electrical power at the correct voltages allowed the traditional batteries to be eliminated at a number of pilot stations and now utilities around the world have an alternative “green” solution for backup power that has a much lower lifecycle cost than the equivalent lead acid system.

C. The Heart of the System

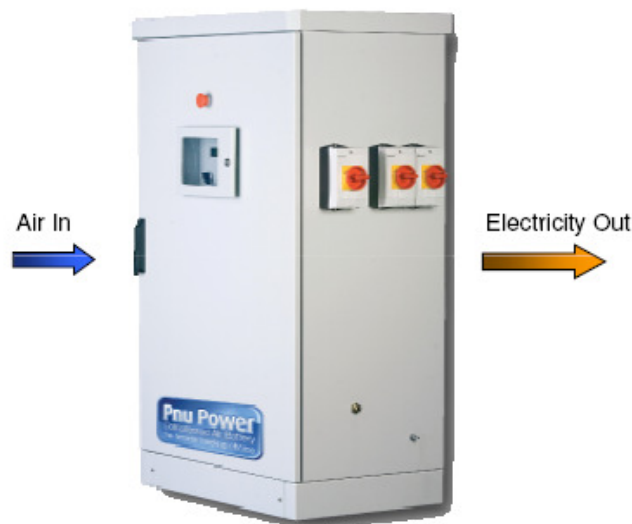
II. DESIGN

A. Voltage Level

The equipment had to meet the strict standards for reliability and safety of a Utility Grid, Transmission System Operator (TSO). The input voltage was 230 Vac single phase which was rectified to provide two isolated outputs, 48 Vdc and 110 Vdc. Pnu Power had previously installed equipment on telecoms sites and had solutions for a range of input and output voltages.

B. Power Level

When the power from both outputs of the system were combined, it exceeded the standard Pnu Power 2kW



The heart of the compressed air UPS system is a scroll expander. This is a complex piece of proprietary mechanical design that is based on a traditional scroll compressor design; the difference being that, it rotates when compressed air is applied (Scroll Expander, Refer to Figure 1). This rotation is converted into DC power with the use of a dc generator.

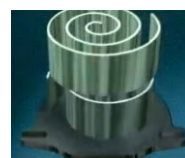


Figure 1 - Scroll Expander

D. Response Time

When the 230 Vac power fails, it is not acceptable to have any break in the supply of power to the DC equipment. This was the major challenge when designing a compressed air UPS system. Within less than a millisecond a signal is sent to a high speed air valve to open and pressurize the scroll expander, this starts rotating and generating DC voltage. The speed of the expander is regulated by adjusting the pressure which in turn regulates the DC bus to balance the generation against the load. The transition takes place in less than 50 milliseconds but even an interruption as short as this is enough to disrupt sensitive electronic equipment so capacitance is added to the DC bus to maintain the voltage until the scroll accelerates up to speed. The equipment works together to provide seamless backup power.

E. Control Electronics

Off the shelf electronics are not available for this sort of application so a control board with a graphical user interface was developed in-house. This board uses an advanced PIC chip to respond to a loss of power and drive the necessary valves and regulators. This board also monitors the air pressure and can be configured to predict the available backup time. Self diagnostics continuously check the system to make sure it is ready to respond.

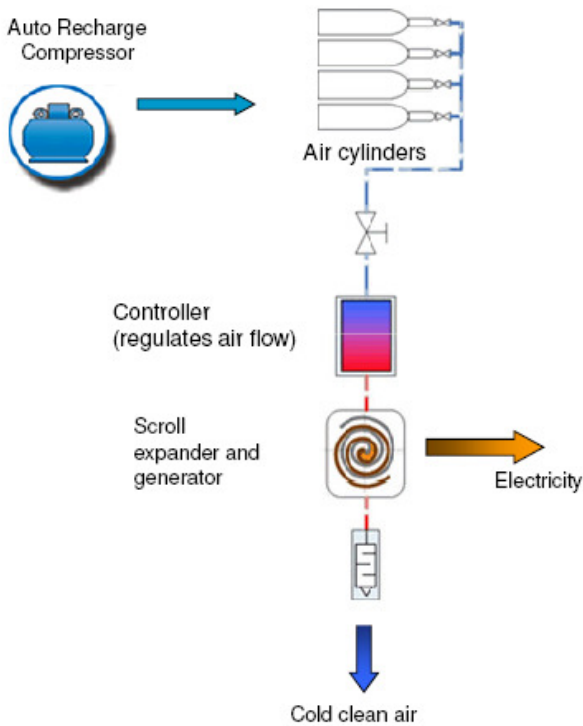


Figure 2 - Schematic of Compressed Air UPS

F. Safety and Certification

Installing equipment in high voltage substations requires evaluation and testing by third party organizations. The National Grid in the UK as with most worldwide utilities require that equipment installed within their substations is registered with the Achilles Certification and a stage-gate approach to product testing has been carried out with factory testing and successful field trials completed before deployment.



Figure 3 - Accreditation testing

G. Testing and Evaluation

A total of 30,000 discharges were completed prior to the systems being deployed to ensure they would support the load when required.

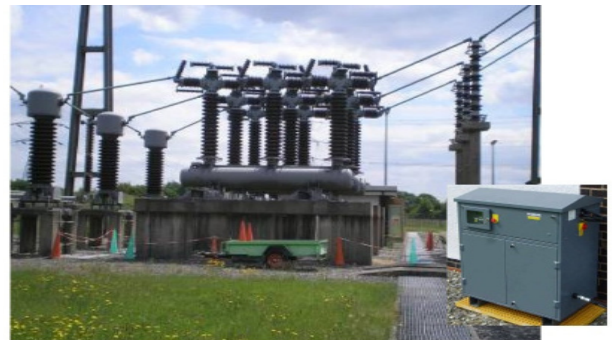


Figure 4 - National Grid UK - Capenhurst Site

H. Hostile Environments

National Grid USA has to cope with more extreme environments than National Grid UK and as such, it was necessary to test the DC2 Compressed Air UPS System in these conditions. One of the benefits of the system is the fact that it can be installed outside which removes the need for expensive enclosures and or buildings.



Figure 5 - Environmental chamber

With this in mind each unit was subjected to +50°C (122°F) and -40°C (-40°F) temperature cycles over a period of weeks. The system has very low standby losses in the region of 30 Watts and as such has very little self heating so for units that operate below -20°C a small thermostatically controlled heater is added inside the cabinet to ensure reliable operation.



Figure 6 - National Grid USA- Barrington Site

I. Reliability and maintenance

The high reliability of the system is achieved by using the very best stainless steel pneumatic components for the drive train and the design of the system that is stationary in standby so wear only occurs when the system is in operation which is typically less than ten (10) hours per year. Maintenance of the system is minimal with a visual check of the power train. The only required maintenance is a check once every ten (10) years on the air cylinders (pressure test) and if a compressor is installed, this must be maintained in accordance to the manual which is a check of the belts every 200 hours and a pressure test to check the efficiency every 1000 which in a normal site would equate to every five to ten years depending upon the number of power disruptions.

J. Total Cost of Ownership

The level of maintenance is a primary concern for utility operators since they typically take a very long term view with their asset management schemes. A battery free solution reduces the number of checks by half and provides a solution that doesn't need to be exchanged every five to seven years as with batteries. In many older sites the operation may be relying on flooded (wet) cells that require a lot more maintenance and special installations in terms of hydrogen monitoring, bonded flooring and eyewash stations. This can all be eliminated with a compressed air solution that can be installed outside freeing up this space for other vital equipment.

Criteria	Vented battery	Compressed Air UPS System
Degradation	<ul style="list-style-type: none"> Electrodes are corroded as soon as it comes in contact with the electrolyte. Electrodes are degraded during charge-discharge cycles. Degradation is a function of depth of discharge 	<ul style="list-style-type: none"> System is stationary during standby periods with no degradation. Degradation does take place during operation. Can be discharged completely with no effect on degradation.
Temperature sensitivity	<ul style="list-style-type: none"> Range of -10 °C to 40 °C. Battery life halved for every 10 °C above rated temperature. 	<ul style="list-style-type: none"> Range of -40 °C to +50 °C Unaffected by extreme temperatures.
State-of-health assessment	<ul style="list-style-type: none"> Specific gravity and cell voltages. Battery monitoring equipment expensive. Battery discharge / capacity tests. 	<ul style="list-style-type: none"> User friendly graphical user interface accurately predicts runtime. Can be done remotely via modem. Quick and real-time assessment by monitoring pressure.
Maintenance requirements	<ul style="list-style-type: none"> Frequent topping up of electrolyte and battery inspections required. Long duration (5 hr) discharge tests 	<ul style="list-style-type: none"> Yearly inspection. 10 yearly cylinder certification Filters and belts on compressor every five years
Safety	<ul style="list-style-type: none"> Indoor units Hydrogen evolution 	<ul style="list-style-type: none"> Outdoor units No hydrogen evolution

I. References

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[3] P. C. Symons, "Opportunities for energy storage in stressed electricity supply systems," presented at Power Engineering Society Summer Meeting, 2001. IEEE, 2001.