# Development of High Efficiency Diesel Electric Generator Set for Energy Projects in Alaska

*Applicant Contact Information*

John Cameron
Marsh Creek, LLC
2000 E 88th Ave. # 100
Anchorage, AK 99507-3804
Tel. (907) 258-0050

*Partners*

Philip Corbin
14209 29th Street East
Suite 105
Sumner, WA 98390-9675
253-826-9002

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|---|---|
| *Total Project Cost:* | $752,787 |
| *Grant funds requested:* | $677,508 |
| *Match committed:* | $75,279 |

## 1. Project Summary

a. Project Description

Diesel electric generator sets are an indispensable source of electrical power in rural Alaska. Because of a large install base and substantial amount of fossil fuel consumed by diesel generators a lot of efforts were directed to improving diesel engine's efficiency thus reducing overall fuel cost and environmental impact.

It is well known that for achieving best efficiency rotational frequency of the diesel engine should be adjusted according to the load demand. However, all commercially available diesel generator sets are manufactured with fixed coupling between the diesel and electric generator. The rotational frequency of an electric generator is fixed by the grid frequency. It puts a diesel engine in position when it is reaching maximum at full rated power and then it drops almost linearly as power demand decreases. Isolated micro-grids are known for high variability of demand. An additional factor is day-to-night as well as seasonal fluctuation of consumption.

The most obvious and well known solution for improving efficiency is decoupling of the diesel engine rotational frequency from the frequency of the electric generator and the grid. Initial attempts to implement this idea were made utilizing electronic conversion. This approach did not receive wide adoption because of excessive complexity. New physical implementation of flexible coupling was recently developed by the company Flux Drive Inc. The diesel-generator set arrangement with the Flux-Drive coupling is illustrated by *Figure 1*.

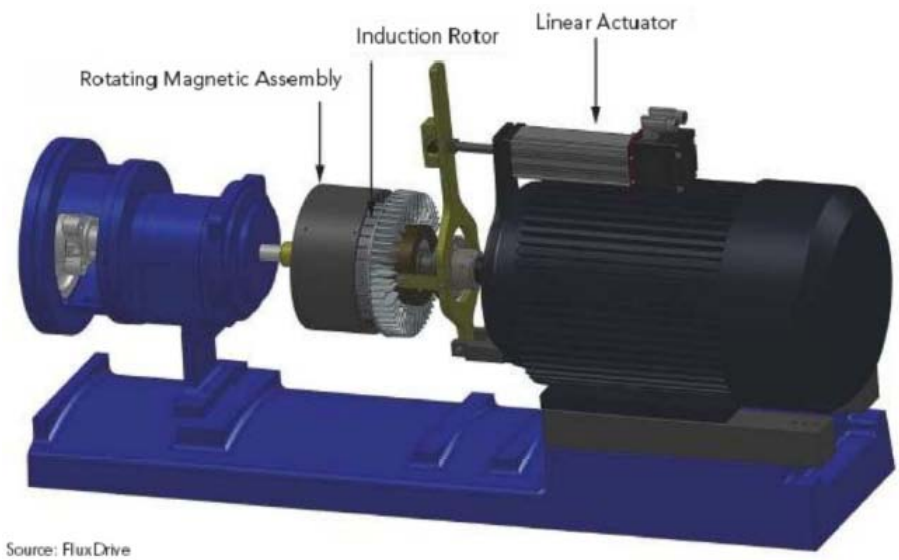


***Figure 1: Diesel-generator set with Flux-Drive coupling***

A Flux Drive is made of two main components: an outer 'magnet can' assembly containing an array of permanent magnets and an induction rotor placed inside the magnet can. These two components are separated by a small air gap (0.070") and have no physical connection or surfaces in contact. As the magnet can turns on the diesel shaft, the induction rotor inserted inside the magnet can (and connected to the generator shaft) starts to rotate due to magnetic induction, which in turn creates a coupling force across the air gap. Slight relative motion (slip) always occurs during the induction process, which is designed to be less than 2 percent at full torque / power. The end result is that torque is driven through the Flux Drive device at an efficiency of greater than 98 percent. The linear actuator is used to control the linear engagement (overlap) between rotating magnets and the induction rotor. As the can and rotor are disengaged, the slip increases allowing the output rotor speed to decrease to a full stop eventually. Thus the Flux Drive provides functionality of a variable speed coupling and well-controlled clutch including final mechanical locking of two shafts for achieving 100% power transfer.

Unique functionality of the Flux Drive makes it very attractive in the construction of the diesel-generator set operating at different rotational frequencies.

The most promising option is to use Flux Drive for switching the diesel engines between two gear boxes, thus allowing the diesel engine to drop its rotational speed from 1800 RPM to 1200 RPM at lower power demand. This alone would provide about 30% savings of diesel fuel. The advantage of this option is high power transfer efficiency and the ability to be used for retrofitting existing generator sets.

Other options proposed by the manufacturer might be capable of providing smoother speed control, but these require further research.

Marsh Creek, LLC is proposing to introduce Flux Drive technology for reducing diesel fuel consumption under conditions of highly variable power demand, in particular:

- Develop an optimal configuration of diesel-generator coupling arrangement utilizing Flux Drive technology;
- Develop a control system for automatic speed control;
- Construct and experimentally test a prototype diesel-generator set utilizing Flux Drive technology at the Marsh Creek site and then at the site recommended by the AEA;
- Design an upgrade kit for retrofitting of existing diesel-generator sets.

b. Project Eligibility

The Flux Drive demonstrational prototype will take 12 months to specify, design, and construct. An additional 12 months will be required to test, modify (as required) and then install and evaluate it within the rural Alaskan village micro-grid. It will facilitate:

- Reduction of fossil fuel consumption by optimizing the diesel engine rotational speed.
- Reduction of energy cost and environmental pollution due to lower fuel consumption;
- Retrofitting of existing diesel generators set for improving efficiency;
- Creation of intellectual property relevant to Alaska thus supporting the state's manufacturing and construction industries.

c. Project Innovation

The project is intended to utilize a recent invention (2007) that was not known to be used for the purpose of reduction of diesel generator set fuel consumption and an impact on environment. Innovations include:

- Development of implementation of the diesel engine speed control for minimizing fuel consumption;
- Development of control algorithms and hardware implementation for speed control;
- Development of diesel engine speed control kit as a packaged commercial product.

d. Project Priority Qualifications

The project satisfies qualification requirements of AS 42.45.375, in particular:

- The applicant is an Alaskan organization
- The project applicant provides matching funds.
- The project has a potential of wide deployment in the state.

## 2. Technology Validation and Research Methodology

a. Objectives

The project's major objectives are defined in the following progression:

a. Identify optimal architectures and control algorithms for the diesel engine speed control utilizing Flux Drive coupling technology;

b. Obtain experimental data validating the design both from the prototype and then from the test run at the site selected for the demonstration;
c. Production of the diesel engine speed control kit for use in Alaska or elsewhere.

b. Methodology

Industry proven combinations of theoretical analysis, computer modeling, and experimentation will be used to accomplish the project goals.

It is anticipated that the ACEP test-bed will be utilized for experimental model validations and testing of the thermal storage prototype.

## 3. Summary of Project Schedule and Summary of Project Budget

The project milestones for the first year will include identification of optimal system configurations, computer modeling, prototype design, construction of a prototype on a test bed, and yearend prototype demonstration and the yearly progress report. The project milestones for the second year will include prototype testing, system design revision, final testing, prototype demonstration, and project final report.

The project estimated schedule and labor cost budget timeline are presented in the table below:

| Year | | Project Tasks | Total Cost | Year Total |
|---|---|---|---|---|
| 1 | 1 | System architecture, requirements definition | $ 50,337 | |
| | 2 | Variable sync and power modeling | $ 174,552 | |
| | 3 | Prototype design and component research | $ 57,414 | |
| | 4 | System integration and SCADA deployment | $ 74,844 | $ 357,147 |
| 2 | 5 | Energy production test round 1 | $ 97,776 | |
| | 6 | Design revision and energy production test | $ 214,158 | |
| | 7 | Project demonstration and final report | $ 83,706 | $ 395,640 |

Marsh Creek and Flux Drive services are estimated at $677,508. Services provided include an estimated 5 days of testing at the ACEP facility in Fairbanks. Matching funds will be provided in form of in-kind in the amount of $75,279.

Total budget of the project is $752,787.

At the end of the first year the project is expected to reach TRL level 6.

## 4. Project Team Qualifications

The project team includes people who have practical experience implementing similar projects or elements of such projects:

***Philip 'Chip' Corbin,*** Founder & President (
Mr. Corbin has 30 years of hands-on experience in marine system design, diagnostics and repair. Prior to Flux Drive, he founded IMPACT Engineering (an ongoing wholly owned subsidiary of Flux Drive), which specializes in machinery vibration diagnostics and repair services provided world-wide. Mr. Corbin graduated with a BE in Marine Engineering from SUNY – Maritime College and also served as a commissioned officer in the US Nuclear Navy.

***John Cameron,*** Marsh Creek, LLC, has 40 plus years of experience in design, construction, and O&M of primary, backup and emergency power generation systems. As Vice President and General Manager of the Energy Systems Division of Marsh Creek he is responsible for overseeing energy systems contracts.

His experience includes management and implementation of over 2,000 power generation systems ranging up to 15 Megawatts (MW) in the United States, Korea, Russia, Saudi Arabia and Kuwait.

***John Lyons***, Marsh Creek LLC, electrical engineer with nearly 30 years of Alaskan experience in power generation and distribution design, construction, maintenance and operations. John brings extensive hands on experience to the team with the integration of wind energy and hydroelectric energy with diesel plants in rural Alaska. John has pushed the envelope for displacing diesel fuel with renewable energy by utilizing electric thermal in integration designs.

***Vladimir Leonov***, Marsh Creek LLC, electrical engineer, PhD, 15-years of experience in BAE SYSTEMS implementing projects involving computer modeling and prototyping of discrete control systems, power electronics, high frequency, microwaves, and fiber-optical systems for defense and aircraft industries.

## 5. Discussion of Commercialization of Funded technology

Proposed Flux Drive coupling is expected to become an integral component of diesel generator sets utilized in rural Alaska. Final product is envisioned as a coupling kit that includes all components necessary for implementation diesel engine speed control. This kit is supposed to be fabricated in Alaska using the coupler from the Flux Drive Inc.

## 6. Signed Applicant Certification

***By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered.***

Signature: John Cameron Date: 03/09/2012

By: John Cameron Title: Vice President & General Manager