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DC Feeders for Remote Loads Using Voltage Source Converters

DC feeders have renewed and topical interest. This 1993 article by Dr. Ani Gole has been dusted off from the archives and is presented as follows. The technology continues to advance. Voltage Source Converters using pulse width modulation at up to 50 MW or more can be applied. Commutation failure is eliminated. Transformers may not be necessary. AC voltage is independently generated and can be rigidly controlled for power quality and stability. DC cables to 100 kV are becoming economically attractive. There is no limit to the number of loads which can be served.

The Prototype scheme:
To demonstrate the concept, the circuit in Figure 1 was simulated using PSCAD/EMTDC. The scheme assumes one supply node and 2 load nodes. The rectifier is a conventional 12 pulse, thyristor based Graetz bridge, rated at 2 MW. The inverters each have a 1 MW rating and are located 150 km and 300 km from the rectifier. The nominal ratings for the dc voltage is 50 kV and for the ac inverter voltage is 13.8 kV. This voltage level provides an acceptable level for the GTO valves in the 12 pulse inverters, allows for acceptable conductor size and has transmission losses of about 4%. The scheme can be expanded to include any number of inverter loads.

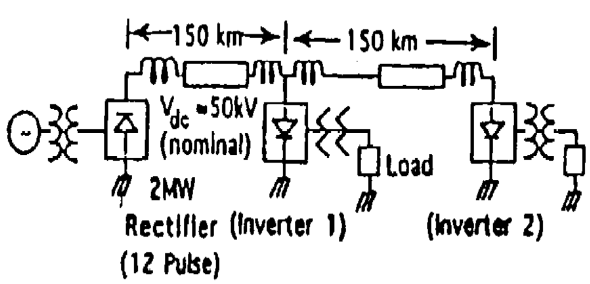

Figure 1: Prototype Scheme

Harmonic reduction in the ac waveform can be achieved by two methods, multi-pulse inverter arrangements or with pulse width modulation (PWM). A multi-pulse valve arrangement of 12 or 24 pulse units was chosen to reduce the switching losses. Minimal filters are used because the filters are not required to provide reactive power.

One PWM switching per quarter cycle is utilized in this scheme to provide control of the output voltage waveform. Figure 2 shows typical voltage waveforms on both the valve side and the load side of the inverter. Note the high harmonic content on the 6-pulse valve side voltage and the sinusoidal output voltage waveform. The voltage control response is presented in Figure 3, where Inverter #2 suffers a full load rejection. Initially both inverters have ac loading of 1 pu at 0.8 pf. The ac voltages of both inverters (Fig 3 b & d) are controlled to rated values via the PWM duty cycle control. (Fig 3 e)

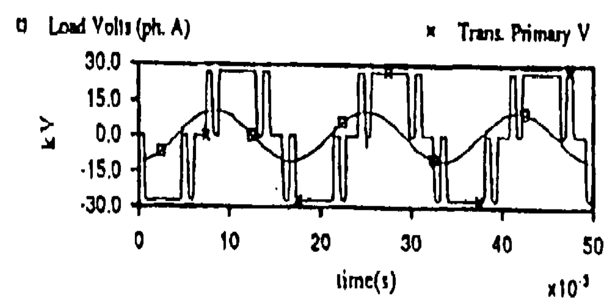

Figure 2: Load and Valve Voltage with PWM

DC faults can be de-energized using the conventional force retard. The thyristor rectifier advances its firing angle beyond 90° and thus de-energizes the line. However, depending on the distance the of inverters from the sending end, a peculiar situation arises as shown in Figure 4a. The current in the rectifier has been extinguished by the force retard action, but a current continues to free-wheel in the back diode of the two remote inverters. The

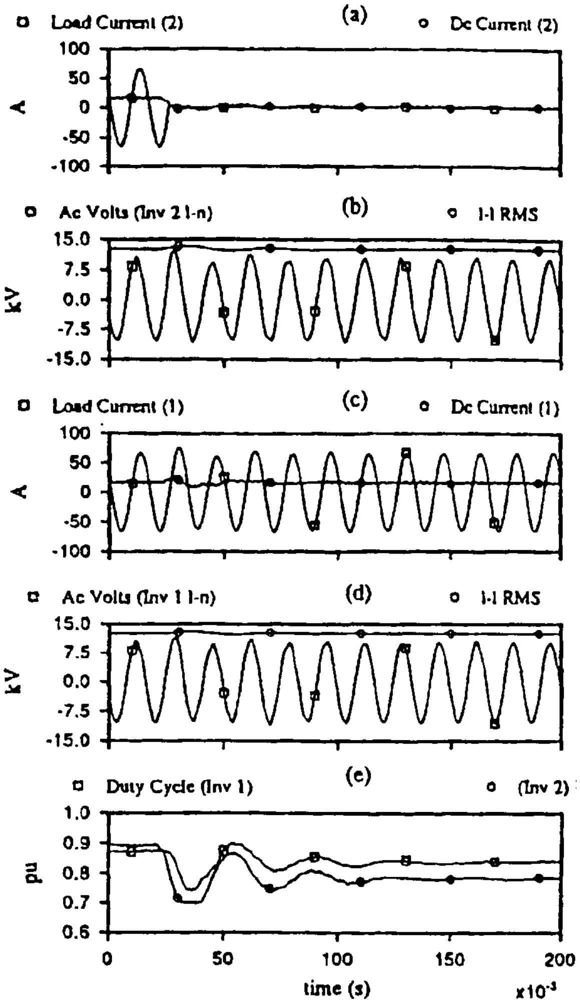

Figure 3: Loss of 1 pu Load at Inverter

resistance in the loop is small, therefore the delay time constant can be quite large, delaying the restart. The problem is overcome with the addition of a diode or valve in series with the inverter. This system can restart within 150 ms after a fault detection. Other faults, including ac system, can be cleared using normal breaker operation. All protective contingencies can be handled on the basis of local measurements thereby eliminating the need for communications between the dc stations.

This article was prepared by Dr. A. Gole based on "GTO based Dc Feeders for Remote Loads", presented at the Canadian Conference on Electrical and Engineering (CCEPE'93) in September 1993. If you have applications for feeding loads to isolated communities, or small taps off EHV transmissions, replacing the shield wire with an energized dc conductor, the Centre can help you examine the Voltage Source Convertor option

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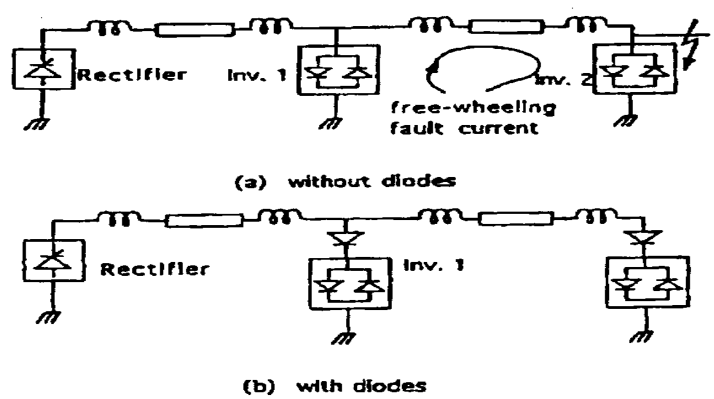

Figure 4 : Fault Clearing Performance

SYSTEM IMBALANCE AND DIESEL EFFICIENCY MONITORING AT LAC BROCHET

The Manitoba Hydro system has identified 4 locations in northern Manitoba where the electrical power will continue to be delivered by diesel generation for the long term. These are remote communities with small distribution systems, typically in the range of 1 to 2 MVA. One such community is Lac Brochet, situated in the north west corner of the province approximately 400 km from Thompson, Manitoba. Access to Lac Brochet is restricted to either air travel or winter ice roads. The diesel fuel is transported to the site using the winter ice roads which are available on a seasonal basis, typically in January and February. Approximately 50% of the diesel fuel cost is attributed to transportation charges.

The Centre recently completed a project to measure any increase in fuel consumption due to load imbalance, as well as evaluate the overall efficiency of the station. This project monitored 46 electrical, fuel flow and temperature parameters at the site in order to determine the overall performance of the diesel generating station. Data was collected over a 18 month period between October 1995 and February 1997.

The Electrical and Monitoring System

Lac Brochet Station has four 600 V generators, three rated at 425 kW and one rated at 175 kW. The station bus with the generators, the delta/star transformer and the monitoring locations are presented in Figure 1.

Fuel Consumption and Imbalance.

Figure 2 presents two charts for same generator operating at different periods of time. Each chart shows the fuel consumption versus the negative sequence current Ia2 for various power levels. Notice that for the 2 different operating periods the same diesel engine consumes more fuel to produce the same power. Fuel consumed due to imbalance is also a function of the electrical loading. The closer the kW loading is to 1 per unit the greater amount of fuel is required due to the load imbalance.

In the first chart, for the generator per unit loading of 0.6 pu. or 250 kW there is no relationship between fuel consumption and load imbalance. At 0.9 pu. loading or 370 kW there is a 5 l/hr or 5.2 % increase in fuel consumption with the imbalance. The second chart shows a 10% overall increase of the fuel consumed at any power level. At 370 kW loading the average fuel consumption increased from 95 l/hr to 104 l/hr. Note that the dependency of fuel from imbalance has disappeared at all power loads. It is estimated that there is an annual 1% increase in fuel due to load imbalance.

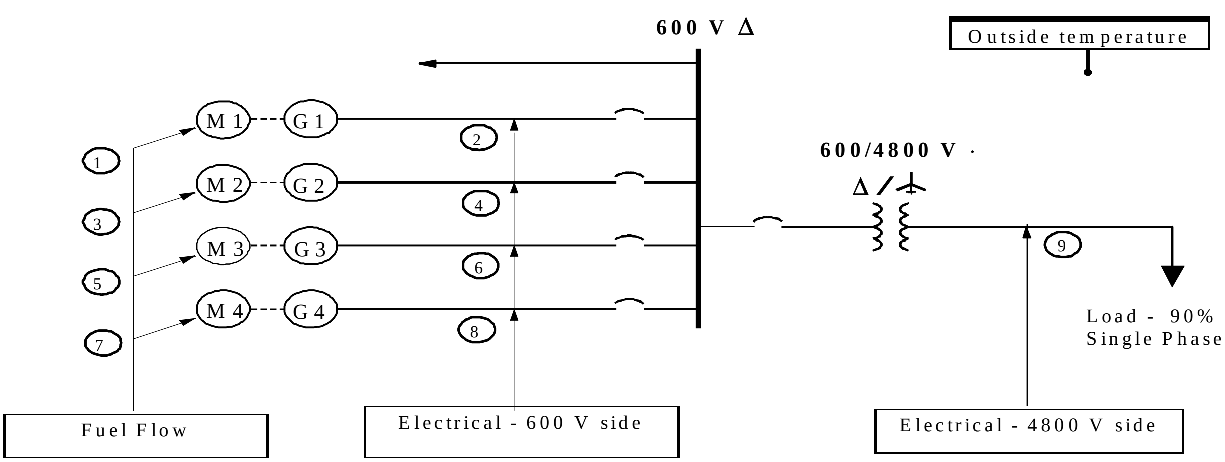

Figure 1 Lac Brochet System

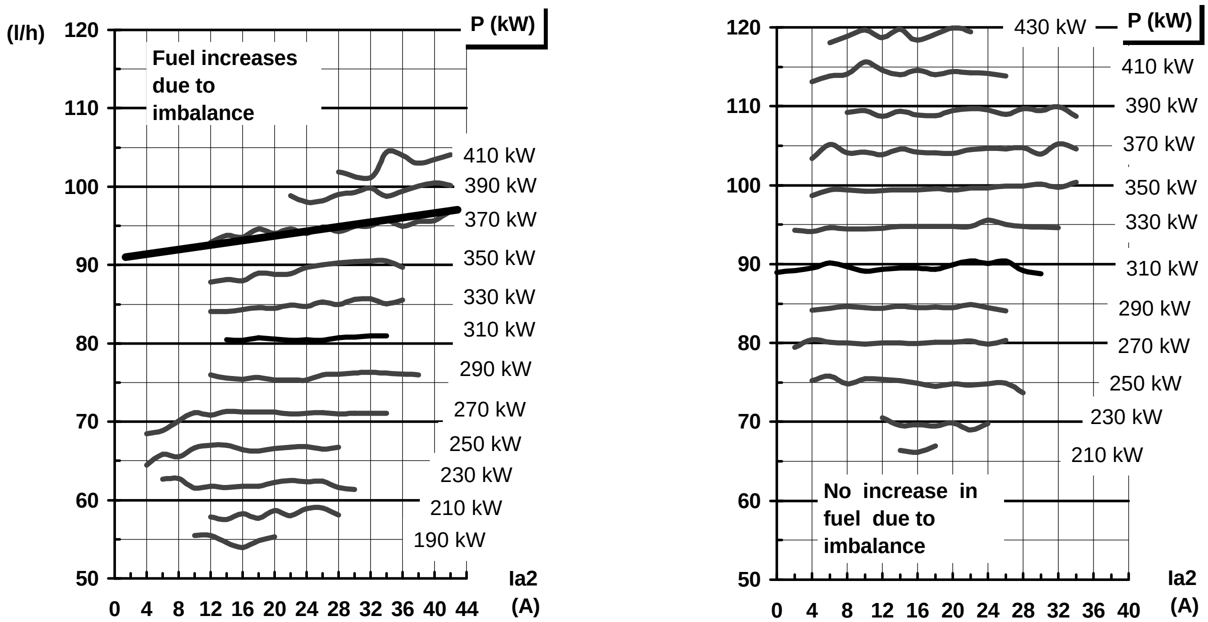

Figure 2 Fuel Consumption versus Imbalance

Results of System Monitoring:

In order to achieve efficient operation of plant equipment, on-line monitoring of system conditions is growing increasingly important. The goal is not to provide more data but to transform the data into information that can be used to make effective decisions for operation and maintenance of the system. Although automatic compensation of the load imbalance is not economically justified by fuel savings in this case, this monitoring program has led to recommendations to improve the operating practices to increase efficiency, improve the process of manual load re-balancing and commenced the development of an on-line kW/litre fuel indicator for efficiency performance.

If you are interested in more information regarding this project please contact:

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