

Practical Application of the Railway Static Power Conditioner (RPC) for Conventional Railways

🔊 Voltage fluctuation, Load fluctuation, AC feeding

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Abstract

Meidensha Corporation has been supplying the Railway static Power Conditioner (RPC) and Single phase Feeding power Conditioner (SFC) for Shinkansen lines as a measure for voltage fluctuations, imbalance of three phases, and for the effective use of transformer capacity at the power receiving point. Recently, we supplied the RPC to Aomori-nishi Substation as our first application of RPC to a conventional railroad line in Japan. Considering that Aomori-nishi Substation is designed to feed electric power for the station and load the rail yard where impedance of the load fluctuates from one of the respective windings and that the back power for the receiving circuit is small compared with that of the Shinkansen line, thorough demonstrative tests were conducted to verify the effect on the power supply system as compensation before the start of actual operations.

1. Preface

In AC electric railroad system, the Scott connection transformer or modified Woodbridge transformer is used to receive three-phase medium or high voltage power and convert it into single-phase AC power, which is supplied to the feeder line. When such transformers are used, three phases at the power supply side will balance if the loads connected to M output and T output of the secondary side balance. However, in an AC electric railroad system, because the loads connected to M output and T output on the secondary side are different and change abruptly, the imbalance between both outputs is frequent, which causes a voltage imbalance and fluctuations on the primary side. The RPC equipment is used to reduce such imbalances or fluctuations via an active power exchange between M output and T output and by compensation of reactive power⁽¹⁾.

We supplied some power compensation equipment for Shinkansen lines but the RPC supplied to the Aomori-nishi Substation was the first one installed on conventional railways, and on-site demonstrative testing was conducted. This paper introduces the details of the equipment and the demonstrative on-site testing.

2. Equipment of Aomori-nishi Substation

At the Aomori-nishi Substation, two 66kV 3-phase power lines are received and 44kV power is fed to the Auto-Transformers (ATs) on the Ou Line and the Tsugaru Line. On these two lines, trains with different power factor characteristics are operating. This substation also supplies power to the premises of Aomori

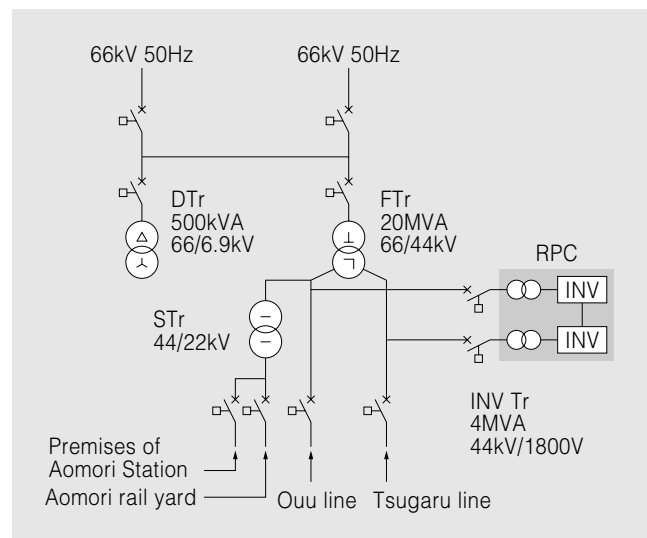


Fig. 1 Single Line Connection Diagram of Aomori-nishi Substation

This diagram shows the circuits that convert 66kV 3-phase power received to two systems of 44kV single phase power using the Scott connection transformer and interchange and compensation of power between phases connecting each phase with the RPC.

Station and Aomori Rail Yard after step down 44kV to 22kV, and accordingly, one of the windings is subject to a nearly fixed load, which is a different condition from normal substations. Fig. 1 shows a single-line connection diagram for the Aomori-nishi Substation.

3. Equipment Configuration and Specifications for RPC

Fig. 2 shows basic configuration of the RPC. The basic functions of the RPC are compensation of the

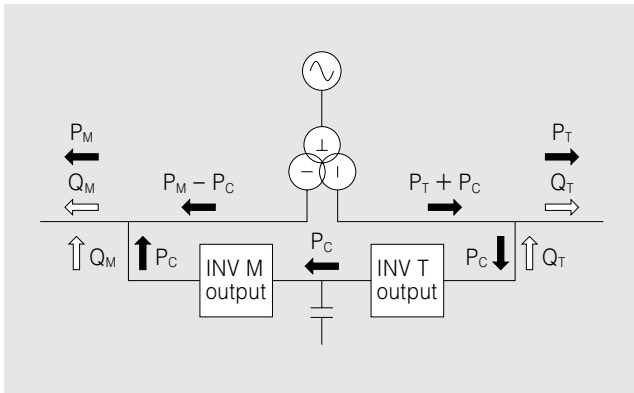


Fig. 2 Basic Configuration of RPC

The RPC connects the inverters installed in each phase of the Scott connection transformer with the DC bus to interchange power between outputs.

Table 1 RPC Specifications

This table shows the rated capacity and principal specifications of the RPC.

Rated capacity	4000kVA × 2
Rating	100% continuous
Rated voltage	44kV
Rated frequency	50Hz
Cooling method	Demineralized water circulation and forced air cooling
Function	Active power interchange control Reactive power compensation control



Fig. 3 Interconnected Transformer Group

The photo shows outside view of the 4MVA, 44kV/1800V inter-connected transformer group.

reactive power in each phase and the interchange of active power between M output and T output. The reactive power of a phase is compensated by inverter control of the respective outputs. With respect to active power, when there is a difference between M output and T output, active power equal to one-half of such difference is interchanged via the DC bus of the RPC from a less loaded output to a more loaded output in order to balance the loads on the secondary side of the Scott connection transformer, which will reduce voltage fluctuations and the imbalance ratio of the power receiving point. Table 1 shows the specifications for the RPC.



Fig. 4 Inverter Panel and Cooling Pump

The photo shows outside view of the inverter panel and the cooling pump for antifreeze solution.

The RPC consists of the circuit-breakers, inter-connected transformer groups, and inverter devices on the respective feeder lines of M output and T output that are interconnected by the DC bus. Antifreeze solution is used instead of demineralized water as the cooling medium of the cooling device for the inverter because Aomori-nishi Substation is located in a cold area. Figs. 3 and 4 show the installed conditions of the inter-connected transformer group and the inverter panel and its cooling pump unit, respectively, and Fig. 5 shows the equipment layout in the substation.

4. On-Site Verification Test

Aomori-nishi Substation, where the RPC was first installed for conventional railways, differs from the substation for the Shinkansen system, such as power receiving from the system with small back power, and it feeds power to Aomori Station and the rail yard. A significant change in the impedance of the feeding system is expected. Accordingly, simulations and studies were conducted in the design stage to avoid resonance with the system and transient instabilities⁽²⁾. The actual energizing tests were conducted to verify that there were no problems due to resonance or instability due to operation for short periods of time in a time zone when the load is small in order to restrict the adverse effect caused by possible problems.

4.1 Results of Compensation Test

Fig. 6 shows the waveforms at various points of the circuit before and after operation of the RPC. The results show that equipment operation was free of abnormal waveforms or resonance.

Fig. 7 shows the feeder load current and FT secondary side current fluctuation extracted from the test results when the RPC was in operation. The graph shows that loads were balanced between both phases, excluding the no-load operation loss during M output

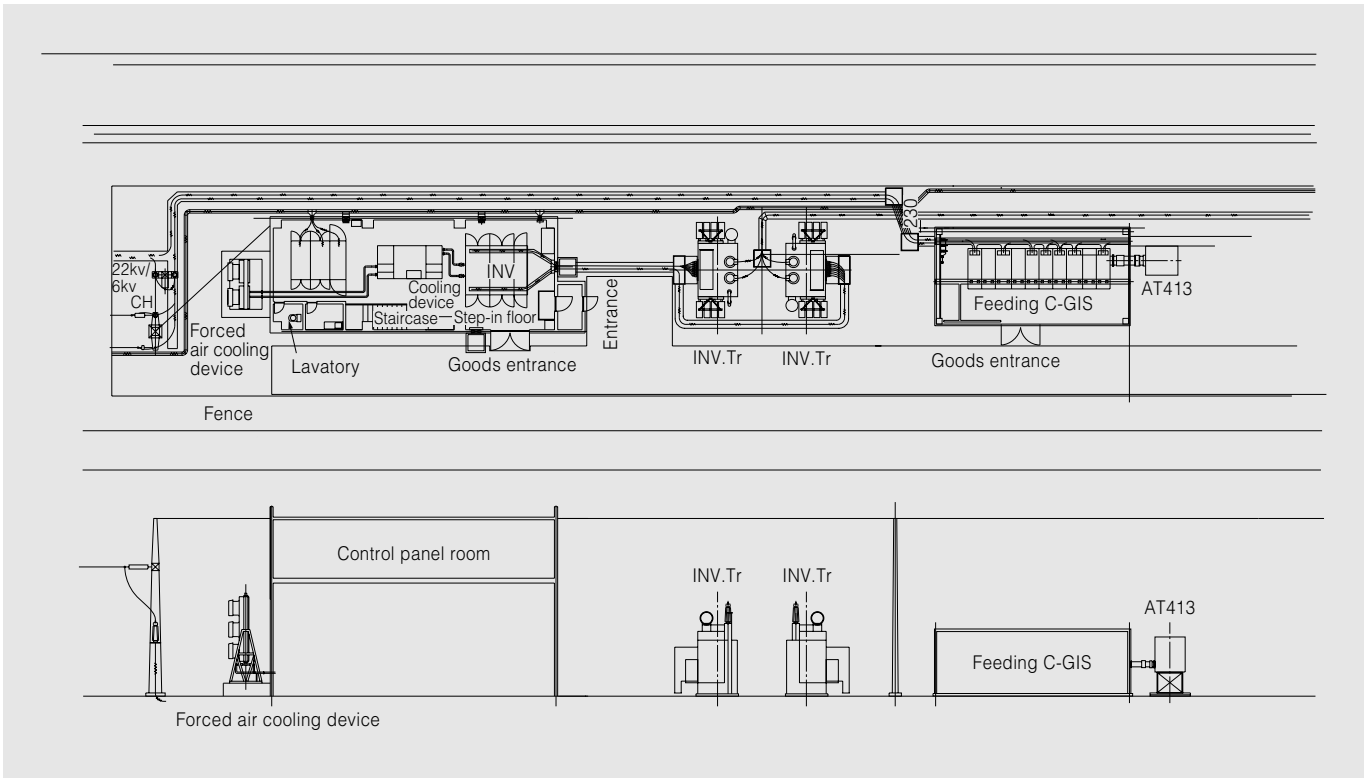


Fig. 5 Equipment Layout of Aomori-nishi Substation

Layout of the substation effectively utilizes the narrow strip of land along the track of the Tsugaru-kaikyo Line.

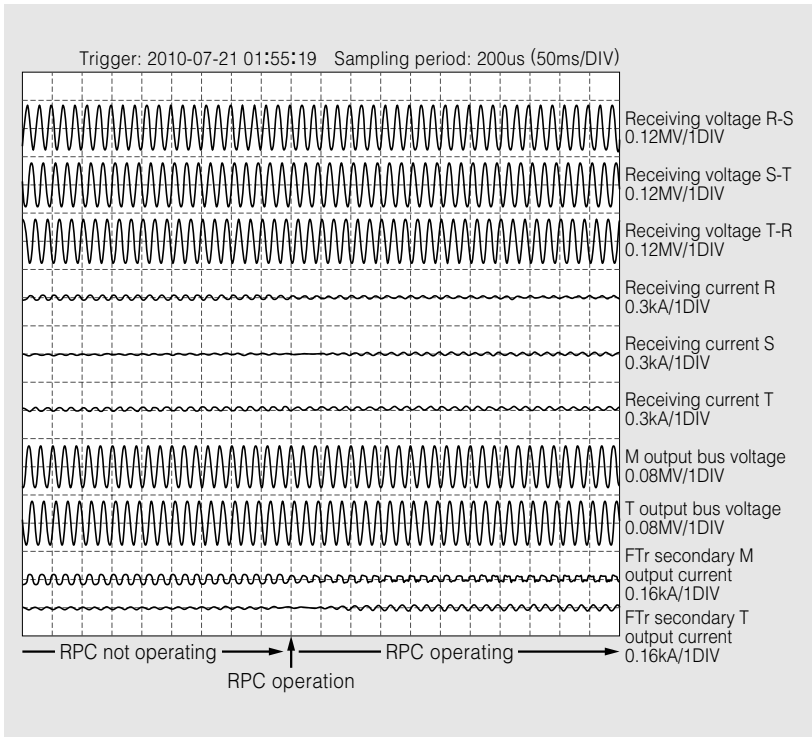


Fig. 6 Specification of Voltage and Current Waveforms before and after RPC Operation

This figure shows waveforms of receiving voltage, receiving current, and feeding voltage and feeding current when RPC is operating and not operating.

with active power effectively interchanged from T output to M output via the DC bus of the RPC even when the load current of T output is absent.

Fig. 8 shows fluctuations in the reactive power of

the load, reactive power of the inverter, and reactive power of FT secondary side extracted from the test results, which shows that reactive power of the load is compensated by the RPC.

4.2 Reduction of System Voltage Fluctuation

Figs. 9 and 10 show the comparison of voltage fluctuations between the states when the RPC was in operation and not in operation. Due to the small short circuit capacity of the substation, voltage fluctuations due to load by the train were significant. As voltage fluctuation reduces to less than a half of the value when the RPC was in operation, the graph shows that the RPC functioned effectively.

5. Postscript

We installed the RPC at Aomori-nishi Substation as an application for conventional railways, and its effectiveness was confirmed. We anticipated potential problems arising from the possible resonance phenomenon between the ground facilities and trains or transient instability due to the

complex feeding system for a conventional railway and ongoing trains of various power factor characteristics in operation. However, the supplied RPC operated well. It was confirmed that the RPC operated without

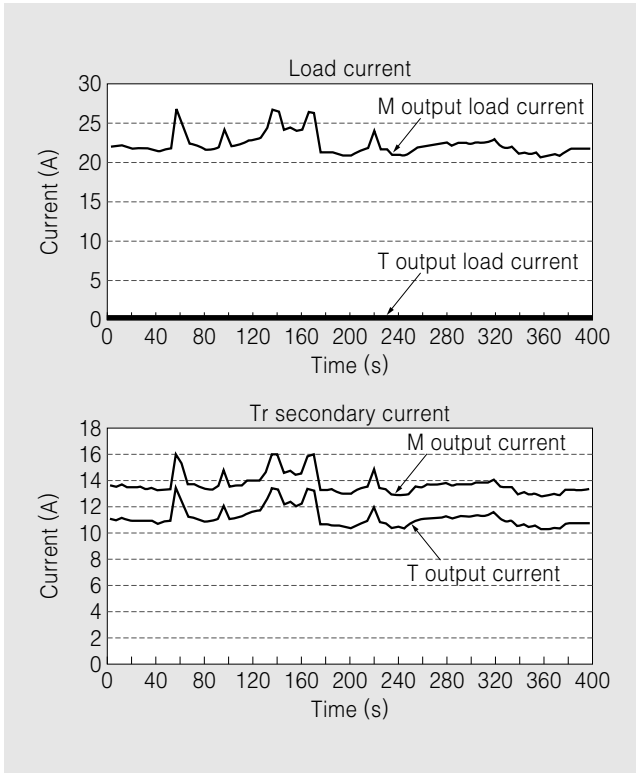


Fig. 7 Active Power Trading Effect by the RPC
The figure shows typical fluctuation of M output and T output current when RPC was in operation.

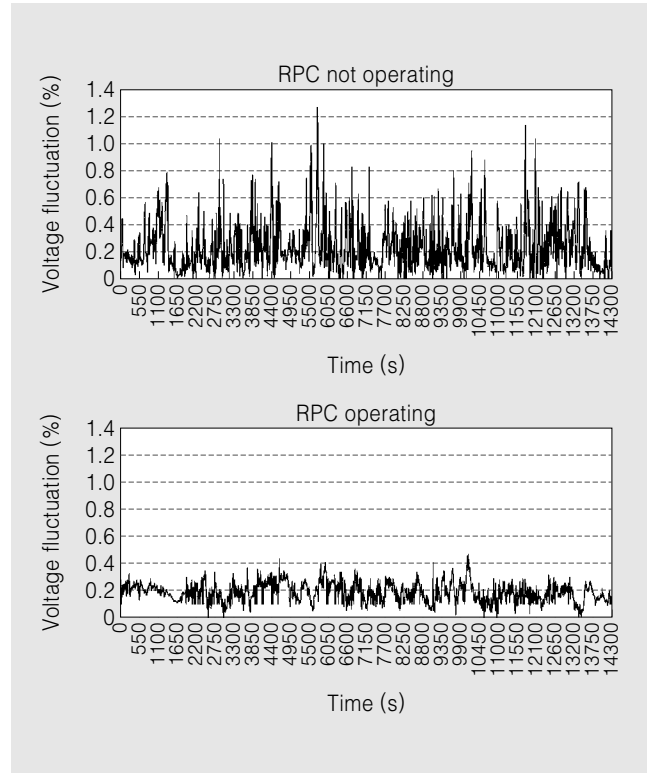


Fig. 9 Effect in Reduction of Voltage Fluctuation 1
This graph shows changes in the voltage fluctuation ratio at the power receiving point with time when the RPC is operating and not operating. It shows that voltage fluctuation ratio decreases when the RPC is operating.

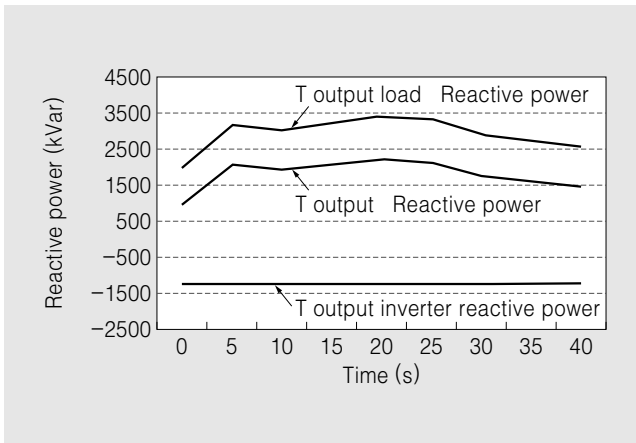


Fig. 8 Reactive Power Compensating Effect by RPC
This example shows reactive power compensation of T output by phase control of the T output inverter.

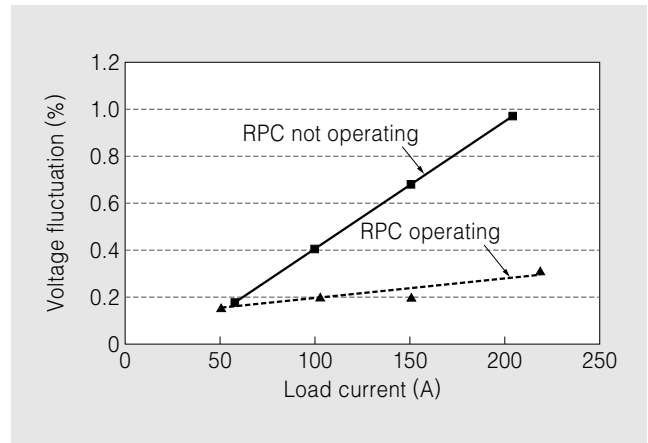


Fig. 10 Effect in Reduction of Voltage Fluctuation 2
This graph shows that the voltage fluctuation ratio at the power receiving point was large due to the increase in the load when the RPC was not in operation, but voltage fluctuations due to the increase in the load were reduced when the RPC was in operation.

problems against inrush current when the train passed through sections peculiar to conventional railways.

Going forward, we expect more demands for quality traction power in various aspects. The use of the RPC in the conventional railroad system will increase. We will continue technical development that meets market needs.

《References》

- (1) Uzuka T, et al.: IEEJ Transactions on Industry Applications, Vol. 115, No. 12, 1995
- (2) Kikuchi S. et al.: 2010 Railway Electric Power Technical Forum, Japan Railway Electrical Engineering Association – Electricity 7 (to be published)