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A Case Study of Transient and Dynamic Performance of Saturated Core Reactor Static Var Compensator

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Over the world it is recognized that a large number of radial transmission lines feeding relatively small loads at their end may show voltage problems, being the regulation an important matter to deal with. Searching for the conformity of the voltage standards, the most traditional solutions find sustentation in the process of reactive compensation. Amongst the mechanisms used to achieve this goal stands out the use of reactive compensators. These devices have in common the characteristic of providing dynamic reactive power injection or consumption in accordance with system requirements.

Thus, the Saturated Core Reactor Static VAr Compensator (SCR-SVC) appears as a good option for the solution of such problem. It is basically given by a suitable combination of a magnetic device built up using commercial magnetic material and special arranged windings and fixed parallel capacitor. This yields to robust equipment, with reduced maintenance, relative good efficiency in the voltage regulation and a short response time. Such advantages, added to the low cost in comparison to the electronic alternatives, become these devices attractive for use in electrical systems.

By describing the equipment throughout the time domain program facilities the focused compensator was implemented and studies were carried out using a real 230 kV system data. This electrical arrangement represents a classical situation found in a growing area of great development fed by a long radial line located in Brazil, Fig. 1. Using this practical example, load variations and voltage investigation at the receiving end were performed to highlight the compensator effectiveness at attending the legislation concerning voltage regulation. To accomplish with the necessary voltage regulation the compensator was selected with a saturated reactor of 25 MVAR and a parallel capacitor of 15 MVAr. The results are then shown and discussed to enhance the transient and dynamic behavior of the overall electrical complex at the occurrence of equipment inrush and sudden load reduction.

The results selected to be given and discussed in this paper are related to two situations. One refers to the occurrence of a sudden load reduction of about 70% of the original value and the other to the equipment energization.

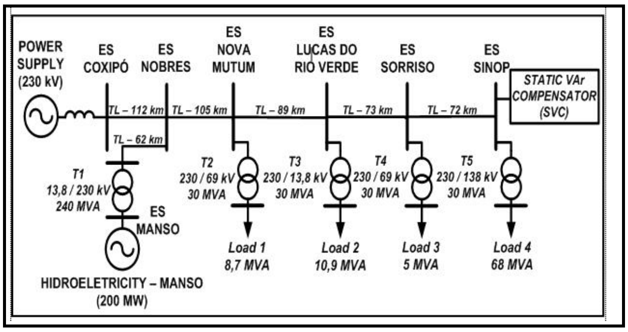

Fig. 1 – Single-line diagram for the electrical system.

A. Abrupt load reduction with no SCR-SVC

This situation corresponds to the system behavior provoked by a sudden load reduction of 70% at the final consumer with no static compensator inserted. Priory to the load change the rms voltage was found to be 217.6 kV. This value is 5.4% lower than the rated voltage. This implies that the system, in its original situation, does not accomplish the standard requirements. At t=1s the load reduction occurs and a consequent voltage increase of 6.89% in relation to the rated voltage is found at the 230 kV SINOP busbar. This phenomenon was programmed to last for 0.5s and all over this period the voltage rms value went up to 245.7 kV.

B. Abrupt load reduction with SCR-SVC insertion

The same previous operation was repeated with a 25 MVAr saturated core reactor and a 15 MVAr fixed capacitor bank forming the SCR-SVC. The physical location where the compensator was installed can be seen in Fig. 1.

The effectiveness of the static compensator in maintaining the voltage at Sinop 230 kV busbar within the rms voltage limits defined by the standards can be easily seen throughout the regions A and B, as given by Fig. 2.

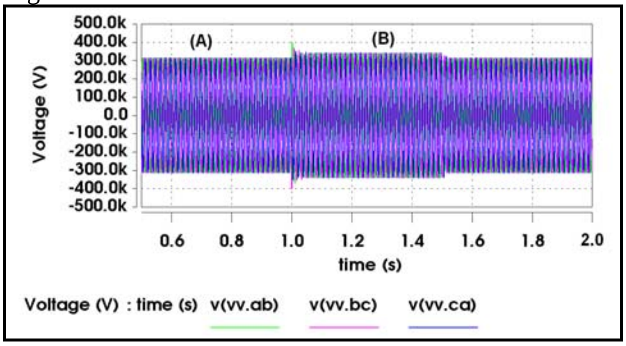

Fig. 2 – Instantaneous 230 kV busbar voltage at Sinop load with compensator insertion.

Before the load reduction the voltage is 222.4 kV which is 3.3% below the rated voltage. During the event the voltage level has raised to 238 kV, i.e. 3.48% above of the rated voltage. After t≥1. 5s the voltage comes back to 222.4 kV. To provide the necessary compensation performance, the saturated reactor acts in such a way to absorb reactive power from the electrical system.

By recognizing the fact that the saturated reactor generates harmonic currents having the same order as a 12 pulse rectifier, the busbar voltage waveform is further considered. The THD found at the 230 kV busbar is around 2.7% and the individual components are in agreement with the expected frequencies.

C. Transient caused by the compensator inrush

As the saturated reactor compensator combines an electromagnetic device with a capacitor bank, the transient behavior involving the equipment operation under this situation must be deeply investigate to prevent possible operational impacts upon the overall system.

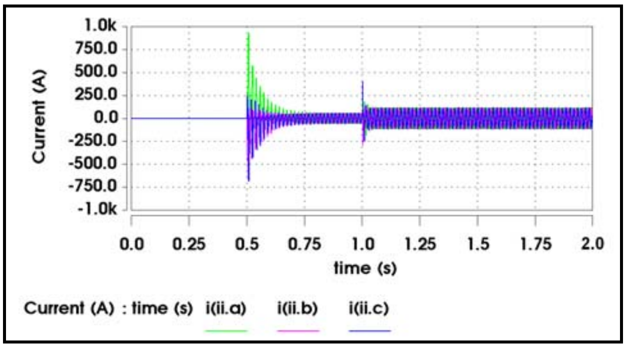

Fig. 3 – Saturated reactor inrush phenomenon.

In this way, Fig. 3 illustrates the individual inrush associated to the reactor connection and later the capacitor entrance in operation. At t=0,5s occurs the saturated reactor insertion and 1s counted from this moment, the capacitor is switched on. Therefore, the static compensator insertion was split in two stages with the objective of attenuating the transient phenomenon.

The results show that the maximum peak found for the transient current at the reactor connection is related to the line A. This value reached 933A which is about 10.5 times the equipment rated current. The reactor reached its steady state condition in about 10 cycles. Once the capacitor is connected, a new peak current can be detected. This highest level occurred to line C which shows a peak value of 402A. This is in total agreement with conventional capacitor inrush phenomenon.

D. Saturated reactor steady state current waveform

The saturated reactor current waveform associated to the e static compensator action due to the abrupt load relief is given in Fig. 4. Both regions A and B are shown. The first corresponds to the operation with the original load and the second one to the partial load rejection condition. The later situation produces the reactor operation so that the device drives 25 MVAr of reactive power.

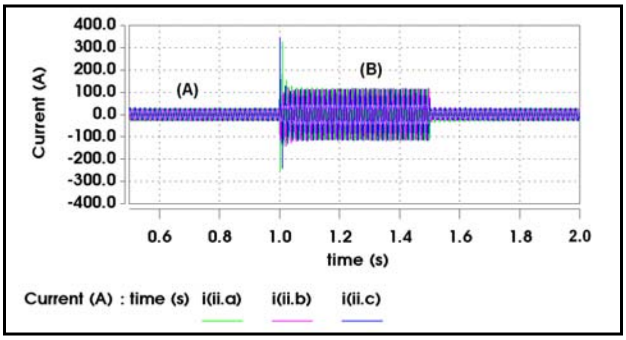

Fig. 4 – Current waveform associated to the saturated reactor unit with normal and reduced load conditions.

The region A (original load) of Fig. 4 provides a clearer view of the reactor current. The rms value is around 19.2 A. This is roughly 30% of the reactor rated current. In a complementary way, the region B details the current waveforms related to the saturated reactor during the operation with Sinop load reduction of about 70%. The presence of the saturated reactor has kept the voltage within standard limits and to achieve this goal its current has gone up to 61.6A. i.e. 98% of the corresponding rated current. The current THD has reached roughly 27.5% with the 11^{th} and 13^{th} components being the most relevant ones. This is in close agreement with expected values and orders as the Twin-Tripler reactor arrangement has been utilized. The results related to the harmonic orders are in accordance with the general expression 12k±1.

Therefore, this paper has focused an old fashion type of compensator which has been considered for specific situations where the voltage regulation requirements are not so strict. By modeling the device in a time domain program it was possible to estimate the transient, dynamic and steady state performance of the overall arrangement. To enhance the program potentiality and the static compensator effectiveness in regulating the voltage level, an abrupt load variation was considered to the investigations. In addition to the operational advantages associated to the use of saturated reactors, it has been shown that it has drawbacks such as harmonic distortion and inrush phenomenon. These aspects reveal that side effects should not be forgotten and they point out to the need of complete studies before the solution is implemented in real schemes.