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STRATEGY TECHNIQUE THE IMPLANTATION FUNCTIONAL IN COMPENSATION REACTIVE SERIES MODULAR

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Job linked to the Project of research and Development (R&D), financed by CPFL: PA3052 – Systematic Application of Compensation reactive Series in networks of Distribution with Control and Protection.

Abstract: The present job presents the methodology developed for implantation of the use in Bank in capacitor series in mode expeditious, without to involve studies technical exhausting. O BCS designed has the flexibility in location in between feeders, as well as can be reproduced in large scale. The research presents a paradigm shift in the use of BCS, at the place in to meet one demand specific, feeders that could be candidates for installation, and a standard BCS was designed that meets most, at specific points. This methodology is a contribution technique for implantation and innovation of the use of BCS, and it is being developed in a project in Search and Development (R&D). At the time the CPFL concluded you studies and it is at phase in acquisition from materials and equipment for 3 BCS to be installed in 2021.
Keywords: Compensation reactive Series, Planning, Series Reactive Compensation, Subsynchronous Resonance, Power in Short Circuit, Quality in Energy.

INTRODUCTION

The main factor what triggered in the study and use from Bank series capacitors (BCS) in power distribution networks. energy electric he was the compensation reactive what allows to maintain adequate quality levels in the distribution system, in situations no conventional.

The installation of the Serial Capacitor Bank in the distribution It is one alternative, what in some cases, if show more effective, faster and more economical than some equipment already commonly used to regulate the voltage level, such as parallel and/or regular voltage capacitor bank. These, in some situations, do not provide the levels adequate quality of supply established by the Module 8 of procedures in Distribution in Energy electrical at the System Electric National (PRODIST), mainly for the speed at operation (Indices in Factor in Impact) [1]. In addition, from that the installation in BCS he can to postpone the carrying out works in the electrical system, such as construction of new substations, transmission lines and new feeders. These works have a cost high and can be postponed, making the expansion in loads new or existing.

One of the factors that determined the need to use of Bank series he was O increase at demand in energy electric, due to growth in loads mainly in industries and agribusiness in locations far away of the source. You main causing these problems are induction motors (MIT), rectifier bridges, irrigation systems, among others that require one compensation in reactive most effective and no static and a quick adjustment of the mains voltage, something that is not possible in to be done with regulators in voltage. The use of BCS allows instantaneous voltage regulation and provides a reactive proportional to the chain of the charge what it is downstream of the equipment, enabling the activation of engines and improving the levels of tension.

CPFL is a pioneer company in the installation of series capacitors in distribution systems, having a history of deployments, which will be addressed in this work. At the moment, the CPFL it has a project R&D, what develops an application methodology and the elaboration of a database series modular, from mode expeditious.

The job in development of the search includes at following features main: fast implantation and well as relocation; VTCD mitigation on clients due to operation of loads, Factor in Impact; Compensation instant; Smaller Investment compared to new substation, re-conductor; Equivalent cost The RTs.

Therefore. the proposal of this project in R&D It is a change in BCS application paradigm used until the present day, for one

Strategy technique Functional in select you feeders that are candidates and identify the points favorable the installation.

COMPENSATION _ REACTIVE _ SERIES (CRS)

the compensation series in the distribution network is realized through of the installation in capacitors connected in series with the objective of reducing the reactive impedance of the system in the installation point. Reactive impedance compensation may be carried out in part, in whole or even with about compensation, due to the insertion in one reactance negative in the circuit. This way, the series capacitor provides potency reactive proportional to the load that it is downstream, providing a reduction in the voltage drop along the feeder. Although he must to be considered what the reactive injected by the BCS depends on the reactive power demand from the loads. Thus, the voltage rise will depend on of the compensation factor and the demand of the reactive flow from of the load downstream to the bank.

The effect of the series capacitor on the voltage drops across a line can be better understood by considering the equation below:

$V = I. R. \cos Y + I. X_1.\text{sen } Y$ (1)

Where: V - fall of the tension in line

I – chain at line

R – resistance inductive of the line

X_l - reactance inductive of the line

Y – angle of lag in between The voltage and the chain

taking up in consideration the reactance capacitive of capacitor in series, xc, a equation above stay:

$V = I. R. \cos Y + Y. (X_1 – X_C). \text{sen}$ (2)

As a function of the value of X_C, the second term of the latter equation can become equal to zero or even negative, or for example: series capacitor can compensate for voltage drop due to the inductive resistance of the line and the drop in tension due The resistance thereof.

O capacitor in series It is particularly useful in networks extensive with high voltage fluctuations due to the characteristics of operation of loads like the machines soldering electric, arc furnaces, motors starting, variable loads, between others. With the application of the capacitor in series it is possible to almost instantly reduce transient voltage drop caused by voltage fluctuation, likewise reduces the fall in voltage caused fur growth vegetative in loads.

However, the operation of series capacitors, depending on of grade in compensation, he can cause phenomena undesirable effects, such as sub synchronous motor resonance during O period in match and iron resonance in transformers. Willing to avoid such resonance one can reduce the capacitor bank compensation degree or also, resistors connected in parallel can be used. with O Bank of capacitors.

The iron resonance which refers to the sudden appearance of a self-sustaining tension with high levels of distortion harmonic, occurs when a resonant circuit is created by the BCS and by a transformer connected in series during the time of the energizing. Although this one phenomenon It is relatively rare, visa what, any charge at the side transformer secondary tends to dampen the iron resonance.

HISTORY _ IN CRS

Initially, CPFL used capacitors in series as form in regulation in voltage in cases specific. At the elapse of experiences and of knowledge acquired about its application, the company sought to innovate and developed the Modular Series Compensator (CSM) through the design of Search and Development 96 (R&D-96) [two] and [3]. At the moment, The CPFL also it is working out a new Research

and Development project (P&D-3052), which will address O Subject in banks in Capacitors in Series again, although with one new strand.

The installations are briefly presented below. series capacitors in SDMT made by CPFL and a panorama over the new project.

A. INSTALLATION OF THE BCS AT CITY IN GUAIRA -SP

He was carried out one installation in character experimental at network in 13.8 kV aiming get subsidies for situations similar and to offer best conditions in supply in energy.

It is networking the principle he was chosen by having in View The system configuration, an extensive network, with in low capacity, loading significant and one fall high voltage, even with the use of regulator in voltage. whereas what others loads They were about to be connected in Guaíra, it was necessary to study in improvements at region, at the which he was defined the use in Bank in capacitors in series per to introduce in immediately the benefit expected.

The series capacitor bank, as shown in Fig. 1, it was installed about 7 km of the locality in Guaira and energized in 1967. 14 power units were used capacitors per phase, 50 kVAr, 6.7 kV and 60 Hz each, presenting so 64 ohms per phase and grade in compensation K= 3.44. O value of factor K he was assumed according you studies published for the Allmänna Svenska Elektriska Aktiebolaget (ASEA) – Sweden and the structure for the bank was made in a similar way to that used for a bank of series capacitor in the 12 kV line of Cia Pacific Gas and Electric Co. S.Francisco, Cal, USA.

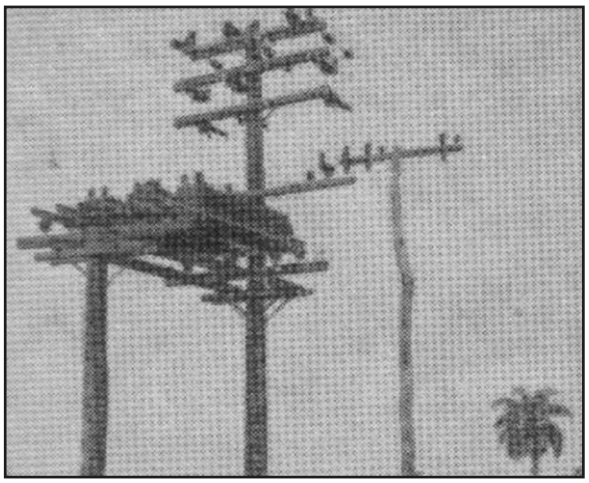

Fig. 1 – Bank in Capacitor in Series in Guaira.

CPFL presented an article in IV SENDI on the topic "Considerations on Capacitor Bank applications in series" in JAN/1969 [4].

This one BCS operated satisfactorily during about 3 years, when a substation was built on site, no being most necessary its use.

B. INSTALLATION OF BCS AT CITY IN SABINO -SP

In the mid-1980s, there was a challenge to adapt the levels in voltage at locality in Sabino, what was supplied fur Substation (SE) Lins feeder, at a distance of 35 km in conductor 6 AWG.

Among at solutions evaluated studied the installation of BCS, experimentally with a compensation of 200% of the line inductive reactance, with 7 capacitive units in parallel by phase. Sabino's BCS operated for 28 years, providing one solution for the region with a benefit technician and economic most high, in comparison to the Installation of Voltage Regulator Banks. The BCS was disabled after the energizing of the IF Sabino 34.5 kV, energized in 2017.

C. INSTALLATION OF THE BCS IN THE CITY IN COLOMBIA – SP

At the year in 2006, in attendance the one farm in plantation of oranges that had

an irrigation system in the municipality of Colombia-SP, where there was a need to activate 61 engines in induction (MIT), with potencies in between 150 CV and 250 CV THE installation of client stayed the 24 km of the IF Colombia 1, serviced with a feeder with 477 MCM CA, with two delta-enclosed voltage regulator banks (15% in regulation) and four banks in capacitors in derivation.

THE farm in question could put on in operation only 40 engines in induction, from 61 what owned, then O drive in any other MIT provoked O shutdown of others engines.

Commonly used solutions to solve problems in voltage, as the regulators in voltage, no would be sufficient because these equipments have a time of performance superior to the time of departure of the MIT. This kind of load requires from the Distributors high investments in construction in new substation. CPFL spotted the opportunity in one new application in BCS, one turn what O project R&D- 96 [5] was ongoing. In this project, CPFL sought to development of a new model of series capacitor, the compensator Series modular (CSM), what allowed the application at any point in the distribution and that could to be reused in others calls through in a rearrangement simple and safe of cells. The Fig. two it presents a diagram schematic of CSM.

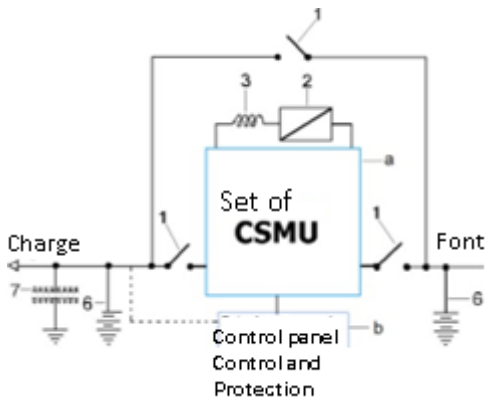

Fig. two – compensator Series modular – CSM

O CSM he was constituted by the following equipment:

- RACK for 16 capacitors per phase;
- Set of 15 capacitors per phase with fuse external. This portion of equipment may vary in a for other Score of system, whose setting defines the capacitive reactance of the CSM (The);
- Panel in Command, control and Protection (B);
- Three-phase transformer for panel power in control and of the coil in opening of the key The vacuum (7);
- Key in bypass (1);
- Key The vacuum: 03 single phase switches (two);
- Reactor with core of air (3);
- lightning rod (6).

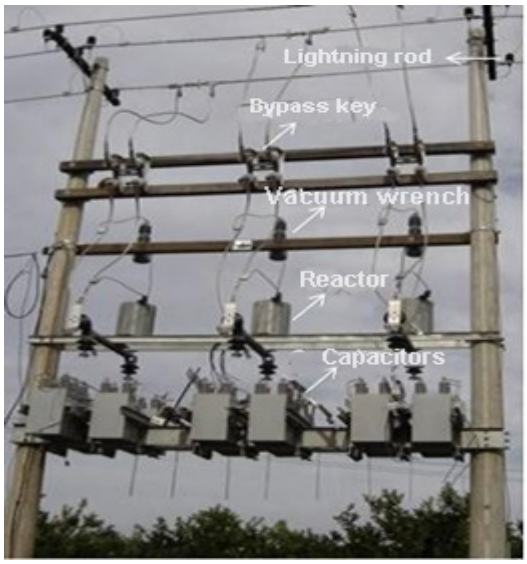

Fig. 3. – CSM-01 Installed in Field.

In order to eliminate the problem of triggering the engines, it was defined that the CSM-01 would then be installed in the feeder that served farm. So, it would be possible to meet at loads of the farm inside of smaller time possible, until the completion of the

new Colombia 2 – Rio Grande substation. of this mode he was chosen a Score The 20.2 km of the IF Colombia 1, where the inductive reactance value was 8.8 Ohms and the value of the capacitive reactance of the CSM was 14.4 ohms, or ie with one about compensation in 164%.

After several tests in crazy were found phenomena in resonance subsynchronous When of drive of 21st motor, indicating the need in Realization in new simulations and studies. The View from that, with the reduction of the capacitive reactance of the CSM to 10.3 Ohms, through the insertion in most cells capacitive, one about compensation 117%, the 61 engines were successfully started and satisfaction of client.

This one Bank stayed in operation up until O Final in 2008, When he was energized to SE Colombia 2.

D. INSTALLATION OF THE BCS AT CITY IN IBIÚNA -SP

Through simulations, it was verified that the feeder that answered part of the area rural of County in Ibiúna, in 23.1 KV, presented spots with voltage in 20.64 kV. With this issue, the supply voltage represented 93% of 22 kV, which is the operating voltage, as shown in Fig. 4. How this is the lower limit of the range considered as voltage properly, according to Module 8 of PRODIST, the power supply was in your limit. Aiming enlarge the capacity in service to new loads, it was defined that the CSM-02, the second prototype of R&D-96, would be installed in this feeder, which also served a large company, located at 11 km of the SE Ibiúna.

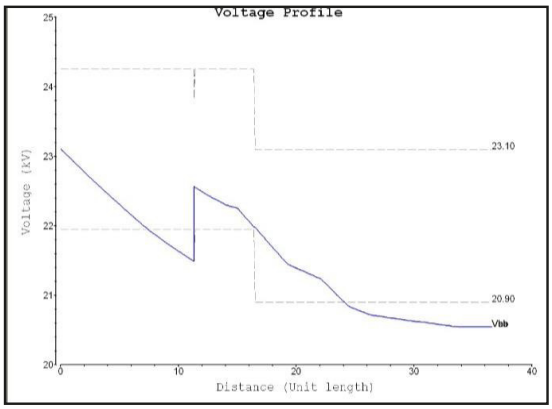

Fig. 4. – Profile of the Voltage at the Feeder – Charge Heavy.

O CSM-02, Fig. 5 he was designed using varistors in oxide zinc as a surge protection device, the what allowed the use in capacitors minors of what O of CSM-01.

After simulations considering at features of feeder, he was defined what O place for installation of equipment would be the 29.5 km of the substation, where the inductive reactance was 17.1 Ohms, and the capacitive reactance of the CSM it must to be in 20.52 ohms (overcompensation in 120%).

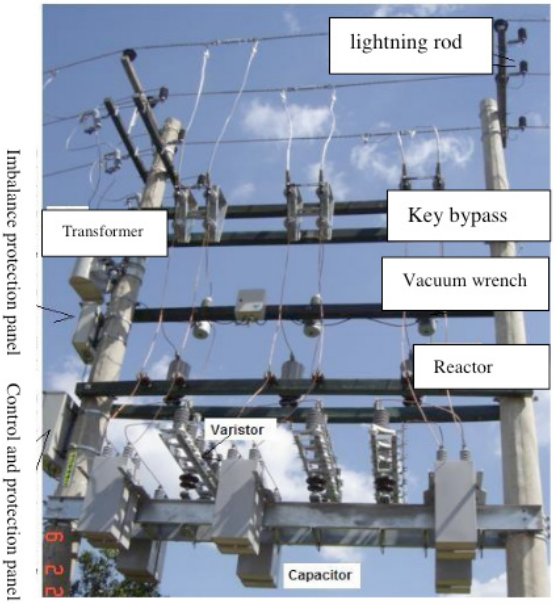

Fig. 5 – Bank Capacitor in Series in Ibiúna – CSM- 02.

THE Fig. 6 show the result of monitoring of the voltage at exit of CSM-02 in two moments, a as Bank off and the other with the bank on. The graph allows to verify the voltage gain achieved with the application of the CSM-02.

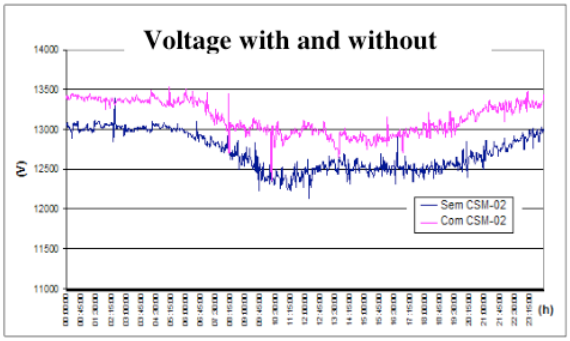

Fig. 6 -Graphic in Voltage (with and without O CSM-02)

From 2012 there was a reduction in the load of the feeder current with the transfer of a large company to the feeder to side, with this, the tension in supply returned to their limits normal, no being most required the use of CSM-2.

E. INSTALLATION OF BCS AT CITY IN SANTA MARIA OF THE MOUNTAIN RANGE -SP

The city of Santa Maria da Serra is served by the feeder that originates from the substation of the city of Brotas, in tension 13.2 kV, with 40km in extension. Up until O year in 2011, The City had a demand of 2.1 MVA and the network configuration until it consisted of 22 km in conductor section 336.4 MCM HERE and 18 km in 4/0 AWG CAA, two regulators' banks in voltage closed in delta and 4 banks in capacitors parallels.

In 2011, an industrial customer in the city requested an increase in demand in 450 kW the value no It is expressive if considered a more robust system or if the load is close to the source, at the however, due to the great distance what if found of the substation and the low value of short-circuit current three-phase at the place, in lathe in 360, at simulations indicated fluctuations above 10% upon activation of the engine of 150 CV of client [6].

The CPFL conceived the opportunity for application in a BCS, and of this turn, the idea was the reuse of CSM-01 originally installed in Colombia, which was out of service since the conclusion of the constructions in construction of the IF Colombia two- River Great.

At the year in 2012 The same industry requested new increase in load, of 565 kW, which was allowed after readjustment of the reactance capacitive of CSM-01 in 14.4 for 16 ohms (increase of the compensation for 97%) and re-conductor in about 5 km of network.

In this case, the CSM-01 made possible the increase in charge requested within the required period and the start of the engine 150 CV had a voltage fluctuation below 5%. of this mode, he was avoided the need in construction in feeder express in about 40 km up until the municipality of Santa Maria da Serra, making it possible to customer service with the smaller cost global.

Until the present moment the CSM-01 continues in operation, enabling the industry stay in operation.

At Fig. 7 it presents the simulation carried out through of the use of software Cyme, with at settings and measurements of the network current, demonstrating what BCS It is essential for the service of the locality until the days of today.

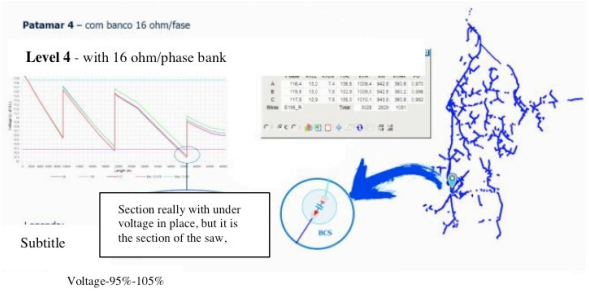

Fig. 7 - Simulation of Capacitor Banks in Series in the City of Santa Maria of the Mountain range us days curren

FUNCTIONAL TECHNIQUE STRATEGY FOR IMPLANTATION OF CRS

Through of installations of BCS, cited previously, performed at the state in Are Paul, The CPFL had a result quite positive, then, all cases in capacitors in series installed on SDMT were successful, especially the model of the CSM, which proved to be an equipment of easy adaptable to the system and relocatable. Furthermore, the cost is relatively low compared to the costs of other equipment already used at network, with the advantage in regulate voltage instantly, raise the short-circuit level circuit, provides potency reactive proportional the demand of loads to the downstream and will improve stability of tension.

However, despite the positive result, some spots in Warning about the place in installation in a capacitor series and the feature of the charge the to be attended. At experiments have shown that when these loads are not predominantly inductive variables, as at the drive-in engines, can to be used one greater compensation in the BCS, like the one installed in Sabino, where a 150% overcompensation was applied. In Colombia it was necessary to reduce the compensation of 164% for 117%, due the predominance in engines. So being, in cases of regions that have areas with large concentration in MIT's, can to occur O phenomenon in sub synchronous resonance, so there is a need to analysis of transients.

PROJECT R&D - PA3052 - THE SYSTEMATIC APPLICATION _ FOR COMPENSATION _ REACTIVE _ SERIES _ IN R EDES IN DISTRIBUTION _

The R&D-3052 project will develop a methodology for application systematic in BCS in the networks in distribution belonging at distributors of Group CPFL Energy, based on assertive simulations and results obtained through in measurements performed in field. This one will prospect and test the technological innovations associated with the practices of control and protection linked The Bank Capacitors in Series, and implantation of the best of these, in the technical standard of its mounting [7].

This one project, differently from projects previous, intends to develop a pattern technician in mounting with sizing of set compensator Reactive Series (CRS) modular Pattern, with system in control and protection tested, defined by the methodology and approved by CPFL. In global form global, the main parameters to be considered in the definition of feeders for establishment in one methodology dispatched in application for systems with compensation series they are related below:

- Feeder Rural with long extension; and low potency short circuit;
- Fur any less two (two) regulators in voltage in waterfall;
- Urban/district loads the most in 20 km of the IF;
- Induction motors at the end of feeders and who have difficulty releasing due to departure of these;
- Existence of potentially disruptive loads at tip of feeders;
- Small locations and reduced demands,

with constraint to build Substation, and problem of stability of tension.

R&D-3052 will define technical alternatives to mitigate the disturbances belonging to system in distribution, when caused by non-linear load variations and/or generation distributed and disturbances at the system electric Preview and posterior the installation of BCS.

In this Strategy technique for implantation in Bank in Capacitor Series, after exhausting studies and simulations, the conclusion was reached to limit the maximum capacity in 1200 amps for the reason in to meet the larger part from feeders, well as it presents a cost attractive eliminating the use of damping varistors, which it is a from components in larger cost and difficulty in acquisition by need of purchases abroad.

For these initial studies were selected 14 15 KV feeders, for modeling in the program ATPDraw, and in parallel at researches for to define the chain in I enjoy circuit maximum what O BCS it must support, considering the maximum number of vessels and the simplicity of not using varistors. It was concluded, through from the simulations, that the maximum value of 1200 A of Icc is proper. Therefore, the simulations were directed to the feeders and in the choice of strategic points that after the installation in BCS no overtake icc adopted. AND after the exhaustive simulations, with technical alternatives of not exceed the limits of supply quality, were chosen 5 feeders, of which 2 selected for BCS installation. To conclude, they were awarded with a dummy load of a large engine (Stove engine Three-Phase Induction (MIT) - 250 CV), at the end of the feeder, verifying the performance and effectiveness of the BCS, without exceeding the quality limits of the feeder and checking earnings considerable.

Therefore, we have a standard Modular CRS, which can be installed in any from feeders researched, in lower cost and with the contour criteria for applications future.

At the moment The CPFL concluded you studies necessary and it is at Stage in acquisition in equipment and materials for mounting of 3 BCS

CONCLUSION

Through of historic introduced, it was proven the efficiency of the application of the Serial Capacitor Bank in the Distribution in Average Voltage (SDMT), improving the stability of the voltage of these systems, providing supply in potency reactive and elevation of level in I enjoy circuit, according checked in cases pictured.

By having as base at various benefits techniques and economic of Bank in capacitor series, The CPFL you see what the same can be used as a reliable, profitable resource and quick implementation in company solutions, such as attendance the big ones load distant of sources, motor drive, voltage regulation, among others what require a study specific most accurate. One highlight is the easy adaptation of the BCS to the system, through one change at combination of cells capacitive.

The new R&D project aims to establish the BCS as a standard model for troubleshooting SDMT, such as as your methodology in application for studies at network.

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