American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-9, pp-248-252
www.ajer.org
Research Paper Open Access

Comparative Review of Multi-Objective Controller based SVC for Power Quality Enhancement

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Abstract: *An electrical power system is serious about quality of electrical power, which has to be assessed to get reliable efficiency of power network. The quality of power is assessed by checking ability of reactive power compensation facilities and their proper control. This paper made a comparative review of various type of reactive power compensation strategies, these controller based reactive power compensation strategies were defined, critically examined and compared. The most promising technology of static var compensator (SVC) is recommended for the realization of an effective, efficient, sustainable, qualitative and reliable electrical power network.*

Keywords: *electrical power, reactive power compensation; Stactic Var Compensator.*

Date of Submission: 01-08-2017 Date of acceptance: 20-09-2017

I. INTRODUCTION

Power quality issues and remedies are relevant research topics and a lot of advanced researches are being carried out in this area. These issues are mainly due to increased use of power electronic devices, nonlinear loads and unbalance in power systems. Dynamic loads cause power quality problems usually by voltage or current variations such as voltage dips, fluctuations, momentary interruptions, oscillatory transients, harmonics, harmonic resonance. According to IEEE Recommended Practice for Monitoring Power Quality (IEEE Std 1159- 1995), Power quality is defined as “concept of powering and grounding sensitive equipment in a manner that is suitable for operation of that equipment.” Electric utilities are forced to operate the system close to their thermal and stability limits due to major hurdles such as environmental, rightof-way and cost problems for power transmission network expansion [14]. The cost of transmission lines and losses, as well as difficulties encountered in building new transmission lines, would often limit the available transmission capacity. Besides, in a deregulated electric service environment an effective electric grid is vital to the competitive environment of reliable electric service. In recent years, greater demands have been placed on the transmission network and the increase in demands will rise because of the increasing number of nonutility generators and heightened competition among utilities themselves. Increasing demands, lack of long-term planning and the need to provide open access electricity market for generating companies and utility customers, all of them have created tendencies toward less security and reduced quality of supply in power system. Contingency analysis is an important component of the security function, which is considered to be an integral part of the modern energy management system at energy control centers. It is also applied in voltage stability to estimate post-contingency P-V and Q-V curves and maximum transfer capability. FACTS devices can improve the stability of network, such as the transient and the small signal stability and can reduce the stress of heavily loaded lines and support voltages by controlling their parameters including series impedance, voltage and phase angle. Controlling the power flows in the network leads to reduce the stress of heavily loaded lines, increased system load ability, less system loss and improved security of the system. In voltage stability analysis, it is interesting and useful to know that the system parameters change prone to voltage stability by means of monitoring scalar magnitudes or indices. Operators can use the indices to know how close is the system to voltage collapse or how much power that the system can supply to loads. The increased interest in these devices is essentially due to recent development in high power electronics which has made these devices cost effective. On account of considerable costs of FACTS devices, it is important to place them in optimal rating and location. There are many optimization algorithms for finding the optimal rating of FACTS devices. The problem of this work is identified as to obtain the optimal solution for voltage instability in the transmission line with the help of FACTS devices and optimization algorithms to keep the voltage profile within the limits, so as to improve the transmission capacity with low loss. The need of this research work has been justified by projecting the statistical data. A detailed literature survey has been done with respect to contingency analysis, FACTS controllers for optimization of power system, Voltage stability indices for optimization of power system and various optimization techniques for selecting the rating of FACTS devices. By revealing the literature survey, contingency analysis with Genetic Algorithm and FACTS controllers (SVC, TCSC and UPFC) with Bacterial Foraging Algorithm has been proposed to accomplish the objective of the work undertaken [20, 21].

The focus of this research is on particular FACTS devices- the adaptive static var compensator. The SVC is indispensable and based on proven technology for power factor correction and reactive power compensation. Power farmers and their users are often serious about increase power cost, reduced system capacity and deteriorated power quality.

Also, the problem encountered by distribution engineer in operation is about recording the power network data on hourly basis. Normaly it tends to errors, loss of time and human energy. So as to rectify that problem wireless technology is recommended.

II. ORIGIN OF THE RESEARCH PROBLEM

Planning reactive power compensation focuses on the optimal allocation and size of the reactive power sources to comply with the applicable reliability standards. The purpose is to find the right trade off between the investment cost of the new volt-ampere-reactive (VAR) source and the benefits in system operation derived from the additional reactive power compensators. Installing compensators to comply with the reliability standards can provide additional benefits such as loss reduction, available reactive power reserves under normal and contingency conditions, improved voltage control, and more room in the transmission and distribution network to move real power and potentially increase transfer limits [19].

Reactive power supply can be divided into two categories: static VAR resources and dynamic VAR resources. Dynamic VAR resources such as static VAR compensators (SVCs) have a fast response time, whereas static VAR resources such as mechanically switched capacitors have a relatively slow response time. Usually, there is a need to install static as well as dynamic compensators in the power system. Indeed, the North American Electric Reliability Council dictates that a proper balance between static and dynamic characteristics must be provided. Static compensators and SVCs are normally operated in voltage-controlled mode (V-controller), implemented by means of a proportional–integral regulator using local input variables [17]. A coordinated voltage control scheme of reactive power devices installed at different substations facilitates achieving a voltage profile across the grid that further improves voltage stability margins, reduces losses, and improves the load ability of the system. Another strategy is to combine the V-controller with other control logic that maintains the output of the SVC at a predetermined VAR level that is not voltage-dependent (Q-controller). It is a coordinated control that actuates on the SVC and the fixed capacitors and reactors installed either in the same substation at which the SVC is installed or in other substations.

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution system, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems [12,13].

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions[19].

III. INTERDISCIPLINARY RELEVANCE

Analog controllers use circuit components such as operational amplifiers, diodes, transistors, pulse transformers, multi vibrators and zero order hold circuits. It consists of large number of components and any change in design requires rearranging the whole circuit and hence time consuming. The major drawbacks are ageing of components, deviation of component values with respect to the environmental conditions and difficulty to produce the controller circuits in bulk quantities. To avoid the limitations of analog circuit controllers, digital controllers are developed. Digital controllers are more flexible, cheap, adaptable and can be easily manufactured in large quantities. Major component of a digital controller is digital signal processor, which receives the input signals, computes the algorithm and generates optimised PWM signals. An improved low cost sensor technology, compact isolation amplifiers, low cost, highly accurate and fast digital signal processors, microcontrollers and application specific integrated circuits (ASICs) have made possible the implementation of complex control algorithms for real time control at an acceptable price. FPGA based implementation was also developed. Anis Ibrahim et al reviews applications of advanced mathematical tools such as fuzzy logic, neural network and wavelet transforms in power quality. Scope for improvement still remains in the configuration and/or control aspects of the active and hybrid filters [10, 11]. A digital controller for an ANN based adaptive shunt hybrid filter, i.e., combination of ANN controlled shunt active filter and adaptive shunt passive filter, is proposed by the author for harmonic and reactive power compensation for nonlinear loads. The load in the system will be varying from instant to instant and computations of reference current are to be carried out repeatedly. If these computed values of reference currents corresponding to different values of load current are used as knowledge base for training ANN network, compensation can be provided at a faster rate. An ANN based digital processor is proposed by the author, which generates PWM signals to switching devices of shunt active filter, and gating signals for thyristors in the adaptive shunt passive filter. It helps the active filter to generate suitable compensation signals and adjusts passive filter component values, based on the harmonic and reactive power compensation requirement of the non-linear load.

IV. TECHNOLOGY COMPARISION

Sr. No.	Parameters	Synchronous Condenser	SVC's			STATCOM
			FC-TCR	TSC	TSC-TCR	
1	Control Coordination	Slow	Fast but System and Control Dependent	Fast but Control Dependent	Fast but System Dependent	Medium and System Dependent
2	Harmonic Generation	None	Moderate	None	Limited	Limited
3	Low Voltage Ride Through	Good	Limited	Limited	Limited	Good Limited
4	Maintainability	High	Low	Low	Low	Low
5	Availability of Spare Parts	Uncertain	Certain	Certain	Certain	Certain Limited
6	Overload Duty Cycle	Well Suited	Suited	Suited	Suited	Suited
7	Losses	Moderate	Medium	Small	Small	Small

Table 1:- Comparison of Different Reactive Compensators

Here, technologies have been examined as shown in Table 1 above, selection of the preferred technology will be made base on the following yard sticks; control coordination, harmonics, low-voltage ride-through, maintainability, availability of spare-Parts, And Overload Duty-Cycle.

Control Coordination: Examining the three technologies, both SVC and STATCOM applications stands for a notable risk of control coordination, making control coordination a challenge in SVC and STATCOM devices. And a plus for synchronous condensers compared to the other two technologies.

Harmonics: Both SVC and STATCOM technologies have the potential to produce harmonics, while the synchronous condenser does not. In addition to not producing harmonics, a synchronous condenser can act as a sink for harmonics in a network were harmonics do occur. This attribute benefits the synchronous condenser.

Low-Voltage Ride-Through: Looking at low-voltage ride through, the SVC performance is less appealing than synchronous condenser or STATCOM. Synchronous condensers are a long-standing answer as reactive power sources that can and do ride-through low-voltage situations [18].

Maintainability: One of the demerits normally connected with synchronous condensers is maintainability due to friction and wear. Static devices do require maintenance of auxiliary cooling systems, valve replacements, and control system upgrades. They also need special training of maintenance personnel who may not be used to working on such devices. Assessing the three technologies, the anticipated maintenance and up-keep costs for synchronous condenser technologies, and that of static technologies are even. In some situation, synchronous condenser maintenance may be simpler than that of an SVC and a STATCOM. Thus, there is no defined advantage in maintenance as regard the technologies reviewed.

Availability of Spare-Parts: One of the difficulties connected with maintaining older equipment has to do with capability to obtain needed spare parts. Advancements in technology are normally regarded as positive in terms of cost, performance or both. On the other hand, old technology is occasionally regarded as obsolete or ineffective, when in fact it may not be. Considering availability of spare-parts; particularly beyond twenty to thirty year window, there is greater certainty of parts and support for synchronous condenser-based reactive power device.

Overload Duty-Cycle: The synchronous condenser is well suited to manage overload duty. Depending on the design of the machine, and ceiling of the excitation system, the occasional overload rating of a synchronous condenser can be twice nameplate or more, for several seconds. This type of duty-cycle favours the synchronous condenser over SVC and STATCOM technologies.

V. RELATED/PROPOSED WORK

Many surveys and literatures have been conducted on performance evaluating the reactive power compensation methods in distribution level. As the permanent connection of the shunt reactors leads to reduced voltage levels and decreased transmission capacity of the lines during full load conditions. Thus, the paper introduces the solution of continuous voltage drop by introducing the Controlled Shunt Reactor which is a thyristor controlled equipment offers fast response time to take care of dynamic

After reviewing various paper, finally came to know that the shunt compensation is the better reactive power compensation technique. The proposed technique is shown in below Figure 1. Now my proposed work is based on shunt compensator i.e Static VAR Compensator (SVC) in order to compensate the reactive power by either absorbing or generating [7,8].

This controlled strategy allows minimizing reactive power flows on the grid and, consequently, reduces losses[15,16]. It has additional feature of providing compensation phase wise under unbalanced loading condition so that the neutral to ground current can be kept practically at zero value. One or more of the following benefits might be realized through the application of this concept:

- Lower real and reactive losses
- Higher voltage stability margin and reactive power reserves
- To relief in maximum demand and effective utilization of installed capacity.
- To wireless transfer and store power circuit data on central computer system.

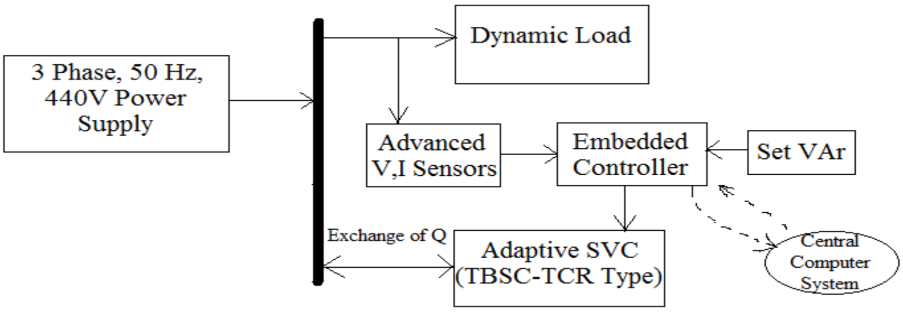

Figure 1: Proposed Research Work

The above schematic represents the power flow control where continuous monitoring of power quality parameters is made. This monitoring is plan by using embedded platform where stepwise compensation is proposed to make by adding capacitive reactive power in bulk steps. The fine tuning of unity power factor is achieved with inductive reactive power by controlling firing angle reactor supply [5,6].

In this above proposed work 3 phase, 440 V, 50 Hz power supply is connected to dynamic load (up to 2-5 kW). The power flow is monitored by connecting Hall Effect voltage and current sensors. The outputs of sensors are given to signal conditioning circuit for boosting the signal strength. Further, we are getting signals in range of +5V/+12V, then these are given to embedded controller.

The role of embedded controller is very important, since it is not only displaying the parameters on display but also taking control actions as per reactive power variations at load side. The power circuit's parameters data are send to central computer system by GSM.

As the majority of the load is of an inductive, non-linear type hence the power factor is always lagging in nature, voltage magnitude profile is below to its normal value and system is taking more current than its normal and containing harmonics in current and voltages. The result of all these problems tends to inadequate reactive power in system, decrement in real power and thereby increasing the various voltage, current and frequency dependent losses in system. The static var compensator (SVC) is heart of this complete research work. The thyristor binary switched capacitor (TBSC) in conjunction with thyristor controlled reactor (TCR) type SVC is proposed to serve the job. In the proposed paper capacitor bank step values are chosen in binary sequence weights to make the resolution small. An analysis of switching transients indicates that transient free switching can occur if the following two conditions are met.

a) The thyristor is fired at the negative/positive peak of voltage, and/or
b) Capacitor is pre-charged to the negative/positive peak voltage.

The first condition can be met accurately by timing the control circuitry and the second condition is only met immediately after switching off thyristor. At the distribution transformer requiring total reactive power Q for improving the power factor from some initial value Pf1 to the desired value Pf2 at the load. This Q can be arranged in binary sequential 'n' steps, satisfying the following equation [3]:

$$Q = 2^{n}C + 2^{n-1}C + \dots\dots\dots + 2^{2}C + 2^{1}C + 2^{0}C$$

In India majority of power substations are going for automation. This work will help in operating substation effectively. The power circuit data such as voltage (in Volts), current (Ampere), power factor, active power (W), reactive power (VAr), apparent power (VA), energy consumption (Wh) are send to central computer system from embedded controller with the help of GSM with the interval of 1 hour. This idea will reduce human energy for recording data every hour, errors in data recording and thereby recording data in systematic format with high accuracy [4].

VI. CONCLUSION

After, technologies have been examined critically, proposed project work is finalized to serve objective to design filter to reduce the harmonics in the system, control the SVC through ARM platform and the values like voltage, current, power factor active power and reactive power can transmit wirelessly through GSM. The SVC can also be fabricated by using IGBT's and testing can also be performed using DSP. TSC-TCR based SVC can also be implemented for SMSL Test System [1,2,9].

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Sameer Usman Bagwan. "Comparative Review of Multi-Objective Controller based SVC for Power Quality Enhancement." American Journal of Engineering Research (AJER), vol. 7, no. 9, 2017, pp. 248–252.