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Pso-Based Optimal Tuning of Control Parameters in Vsc-Hvdc Systems for Improved Power Flow and Reduced Losses

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Abstract - This paper presents the estimation of harmonics in a voltage source converter based HVDC (VSC-HVDC) system for designing AC side filters. The extended VSC and PSO is well known for estimating amplitude, phase, frequency, and harmonic content of a signal corrupted with noise. However, the algorithm suffers from instability due to linearization and costly calculation of Jacobian matrices, and its performance deteriorates when the signal model is highly nonlinear. This paper, therefore, proposes an unscented to overcome these difficulties of linearization and derivative calculations for robust tracking of harmonics in VSC-HVDC system. The model and measurement error covariance matrices Q and R along with the VSC parameters are selected using a modified particle swarm optimization (PSO) algorithm. To circumvent the problem of premature convergence and local minima, a dynamically varying inertia weight based on the variance of the population fitness is used. This results in a better local and global searching ability of the particles, which improves the convergence of the velocity and better parameters. Various simulation results for harmonic signals corrupted with noise obtained from VSC-HVDC system reveal significant improvement in noise rejection and speed of convergence and accuracy.

Keywords - voltage source converter (VSC); HVDC light system; bidirectional HVDC; decoupled d-q vector control; PI tuning; time-domain performance indices; particle swarm optimization (PSO); modulus optimum (MO).

INTRODUCTION

High voltage direct current (HVDC) transmission systems has a very important place in today‟s power system scenario .Very high rating Power electronic devices owing to their fast control capabilities along with the dc voltage makes HVDC system, a more acceptable option for power transmission over large distances, and power injection into load buses without much concerning about system stability and dynamics [1].

Selection of Hvdc

HVDC finds major application when the following transmission requirements are to be met A few among them are [2]:-

Long,Bulk Power Transfer: In comparison to the ac transmission system HVDC can be applied as the best choice as they are economical and accurate, control of power from generation sites to the utilization points is fast and reliable. Cost of conversion equipment employed at the terminals may be high but the line costs are lower than that ac [3].

System Interconnections: HVDC interconnections are superior to EHVAC and find application in many aspects .Power flow can be controlled ,faults are not propagated, no alterations in the short circuit levels at both the ends and enhancement of transient stability of the associated ac networks at both terminals was remarkably seen.

HVDC may also be employed to interconnect two ac systems operating at different frequencies acting as an asynchronous tie. Major task an interconnector has to perform is to transmit dictated amount of power in the desired direction and assist the ac system to enhance transient stability.

Multi Terminal HVDC Interconnection: This recent development in HVDC still increases the priority of its application. Three or more ac networks are connected to one another in an asynchronous manner by means of MTDC system. Large amounts of power can be transferred via dc tie lines to meet the variations in load demand. An increment in stability margins could be noted [4].

Cable Transmission: HVDC is opted for underwater and under-ground transmission of power over a wide area. An ac line cannot be loaded greater than its thermal limit because of the problem of charging currents. On the contrary no charging currents are associated with dc transmission. The above mentioned advantages and the statistical data of mismatch of power supply and demand have led the author to carry out some research in the area of dc transmission. A HVDC link is inherently non-linear in its operation [5].

This basic aspect gives rise to numerous problems in designing suitable controllers under normal and abnormal conditions of the system. The rate of change of dc link current is a non linear function of the firing angles at the converter ends and so it is highly sensitive to their variations [6].

Benefits of Hvdc System
The HVDC system has number of technical, economic and environmental benefits that favors the HVDC transmission instead of AC transmission.

Technical Benefits
The DC-link makes possible to exchange power between the two asynchronous AC networks. The asynchronous interconnection via DC-link isolates interconnected part and can be used for any level of power quality control such as harmonic distortion, unbalance, flicker voltage etc. The asynchronous interconnection facilitates large number of AC system to interconnect across the world such as Japan and South America HVDC link which has different nominal frequency (50Hz and 60Hz) and link between eastern USA and western USA, having different voltage levels [7].

II. FLEXIBLE ALTERNATE CURRENT TRANSMISSION SYSTEMS

With the ongoing expansion and growth of the electric utility industry, including deregulation in many countries, numerous changes are continuously being introduced to a once predictable business. Although electricity is a highly engineered product, it is increasingly being considered and handled as a commodity. Thus, transmission systems are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever. Now, more than ever, advanced technologies are paramount for the reliable and secure operation of SGs. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilisation and control of the existing transmission system infrastructure is required. Power electronics-based equipment, or FACTSs, provide proven technical solutions to address these new operating challenges being presented today.

FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines. Traditional solutions to upgrading the electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, as experiences have proven over the past decade or more, the process to permit, site, and construct new transmission lines has become extremely difficult, expensive, time-consuming, and controversial. FACTS technologies provide advanced solutions as cost-effective alternatives to new transmission line construction (Reed et al., 2003).

The potential benefits of FACTS equipment are now widely recognised by the power systems engineering and T&D communities. With respect to FACTS equipment, voltage sourced converter (VSC) technology, which utilises self-commutated thyristors/transistors such as GTOs, GCTs, IGCTs, and IGBTs, has been successfully applied in a number of installations world-wide for static synchronous compensators (STATCOMs).

III. VOLTAGE SOURCE CONVERTER (VSC)

The voltage source converter (VSC) is the prime unit of a VSC based HVDC system, therefore, its design and performance evaluation is most important to have desired results. This chapter deals with design, modelling and control of VSC for back-to-back AC interconnection and long distanced transmission between two AC networks using HVDC system. The functionality of VSC based HVDC system depends on proper selection of switch rating, interfacing reactor, and DC-link capacitor. The voltage source converter is designed with self-commutated IGBT switch which has combined features of MOSFETs and bipolar junction transistor (BJTs) switch. It has gate, driven like MOSFETs and voltage/current characteristics like BJTs, thereby IGBTs operate at very high current (>1000A) and switched at higher frequency more that 3 to 4 times as compared to GTOs. Therefore, the IGBT switch has high current handling capability and ease of controllability. However, HVDC converters can be switched up to 2 kHz frequency to make the switching loss within acceptable limit.

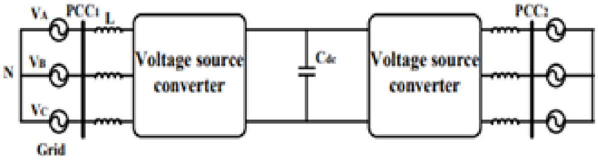
Advantages and Applications Of Vsc- Hvdc
The VSC-Based HVDC transmission has many advantages over the classic HVDC transmission which is based on line-commutated current sourced convertors (CSC), with the thyristor being its switching device. These advantages come from VSC transmission capability of controlling AC voltage magnitude, phase angle and output frequency at its terminals. The main advantages of VSC transmission systems are their ability to x Control both active and reactive power independently x Control reactive power independent of other terminal(s)

IV. BACK-TO-BACK VSC BASED HVDC POWER TRANSMISSION

Back-to-back (BTB) HVDC interconnections are used for power transfer between two independent neighboring AC systems via DC-link. The rectifier and inverter are located in same station having practically zero meter long transmission between them. The BTB configuration is used for number of reasons such as:

- To connect asynchronous high-voltage power systems with different frequencies
- To stabilize weak AC links
- To transmit reliable power
- To control of grid power-flow within synchronous AC systems

The VSC based HVDC system is composed of self-commutated switch, interfacing reactor, DC-link capacitor. The rectifier and inverter are connected back-to-back as shown in schematic diagram of Figure.



V. POWER QUALITY STANDARDS

The AC-DC converters are commonly used in the DC motor drives, high voltage direct current transmission system and adjustable speed drives etc and standards refer to these applications are given in the literatures [IEEE Std. 1030, 1987; IEC 61000-3-2]. In order to prevent the ill effect of harmonics on the utility grids, an IEEE Standard IEEE-519 [IEEE Std. 519, 1992] has been introduced in 1981 as the “Recommended Practices and requirement for Harmonic Control in Electrical Power System” giving limits on voltage and current and it has been revised in 1992. IEEE 519 Standard limits on amount of current that consumer can inject into utility grids and it also places limitation on the level of harmonic voltage that utility can supply to a consumer. The use of AC-DC converters depend on the power involved and applications. The standard practices and requirements for semiconductor power rectifier transformers are detailed in IEEE Standard C57.18.10-1998 for conventional rectifiers.

Particle Swarm Optimization Algorithm

The original PSO suggested by Kennedy and Eberhart is based on the analogy of swarm of bird and school of fish [7]. The algorithm was simplified and it was observed to be performing a solution to an optimization problem. A. Standard Algorithm PSO, as an optimization tool, provides a swarm-based search procedure in which particles change their positions with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience, and the experience of neighboring particles, making use of the best position encountered by itself and its neighbors. When improved positions are being discovered these will then come to guide the movements of the swarm.

The process is repeated and by doing so it is hoped, but not guaranteed, that a satisfactory solution will eventually be discovered [8-10]. The following is the conventional terminology of the parameters in PSO: Let x and v denote a particle coordinates (position) and its corresponding flight speed (velocity) in a search space, respectively. Therefore, the ith particle is represented as xi = [xi1, xi2, ..., xim]. Since m is the last dimension or coordinate of the position of the the ith particle in the search space and so that d = 1, 2, ..., m. The best previous position of the ith particle is recorded and represented as, pbesti = [pbesti1, pbesti2, ..., pbestim]. The position of the best particle among all the particles in the group is represented by the gbest. In a particular dimension d there is a group best position which is gbestd. The velocity for the ith particle is represented as, vi = [vi1, vi2, ..., vid]. The modified velocity and position of each particle can be calculated by using the following formulas:

$$v_{id}^{k+1} = w*v_{id}^{k}+c_1*U*(pbest_{id}^{k}-x_{id}^{k})+c_2*U*(gbest_{d}^{k}-x_{id}^{k})$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}$$

i = 1, 2, ..., n; d = 1, 2, ..., m
Where
n number of particles in a group;
m number of members in a particle;
k pointer of iterations (generations);
w inertia weight factor;
c1, c2 acceleration factors;
U uniform random number in the range [0,1];
xk id, vk id the position and velocity of the ith particle in the dth dimension at iteration k;

The search mechanism of the PSO using the modified velocity and position of individual based on (1) and (2) is illustrated in Fig. 1.

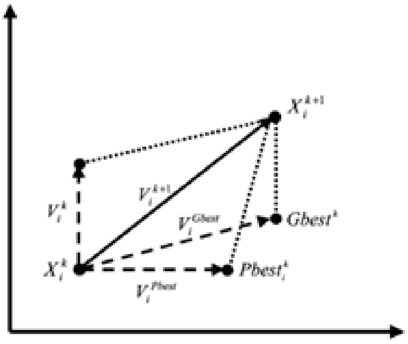


Fig. 1. PSO search mechanism

In the above procedures, the velocity should between v min d ≤ vid ≤ v max d If v max d is too high, particles might fly past good solutions. If v max d is too small, particles may not explore sufficiently beyond local solutions. In many experiences with PSO, it is often set at 10 - 20% of the dynamic range of the variable on each dimension [10]. The constants c1 and c2 represent the weighting of the stochastic acceleration terms that pull each particle toward the pbest and gbest positions. Low values allow particles to move far from the target regions before being dragged back. On the other hand, high values result in sudden movement toward, or past, target regions. Hence, the acceleration constants c1 and c2 are often set to be 2 according to empirical experience [10]. Suitable selection of inertia weight w in (1) provides a balance between global and local explorations, to find a sufficiently optimal solution. As originally developed w, often decreases linearly from about 0.9 to 0.4 during the run. In general, the inertia weight is set according to the following equation:

$$w = w_{max} - \frac{(w_{max} - w_{min})}{iter_{max}} \times iter$$

Where itermax is the maximum number of iterations (generations), and iter is the current number of iterations.

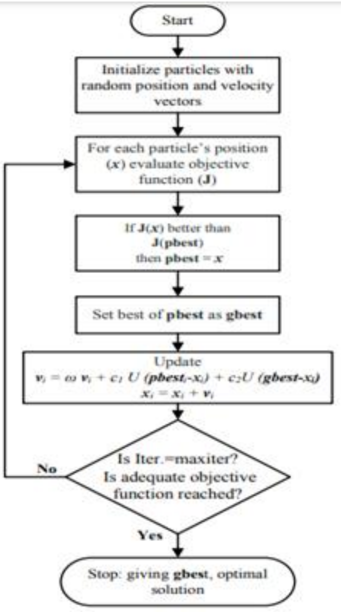


Fig. 2. PSO algorithm flowchart

Results and Discussions

The proposed approach is implemented on the VSC-based HVDC system shown in Figure 1. The PSO algorithm was used to minimize the time domain based performance indices as discussed in Section 6. The PSO parameters selected for the optimization process are given in Figure.

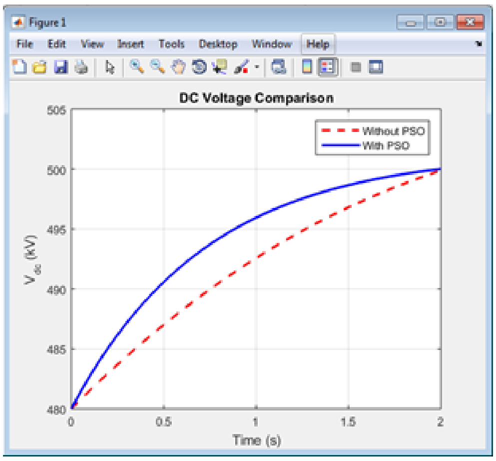


Fig.3. PSO VDC link voltage.

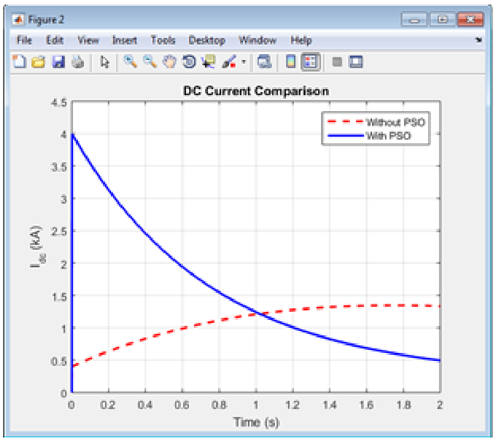


Fig. 4. Idc link current.

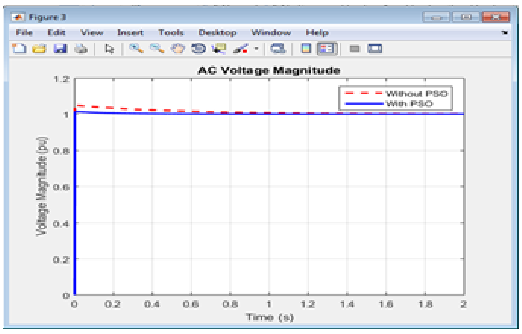


Fig. 5. Voltage Magnitude.

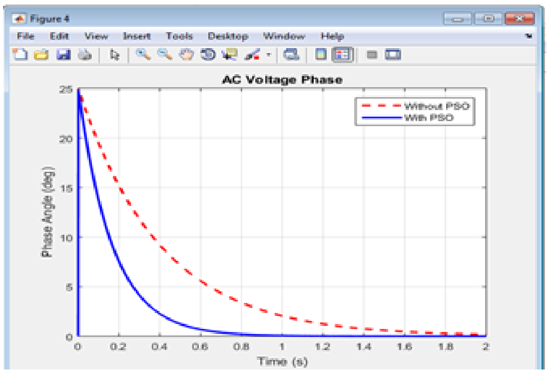


Fig. 6. AC Voltage Phase.

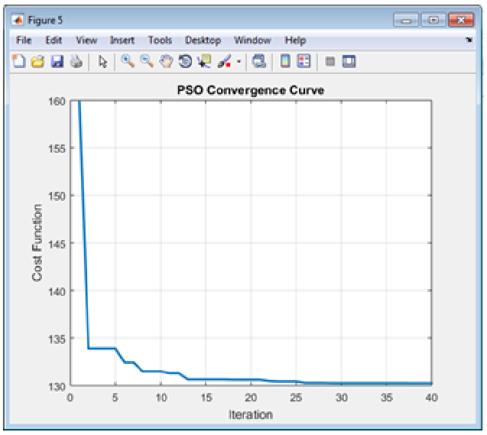


Fig. 7. Cross Function.

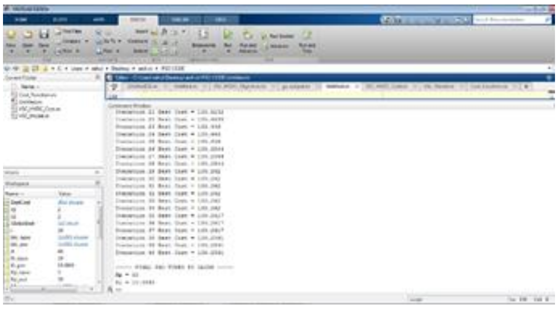


Fig. 8. Output Window.

With Kalman Filter

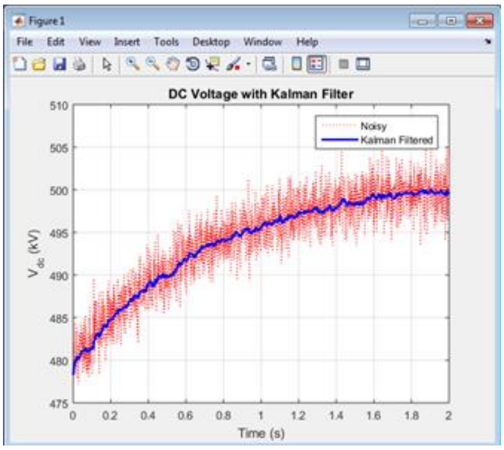


Fig. 9. KALMAN FILTER Outcome 1.

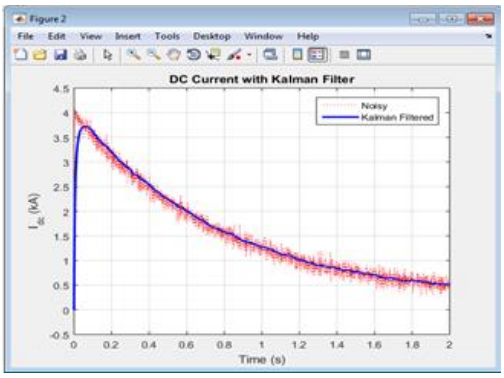


Fig. 10. IDC filter impact.

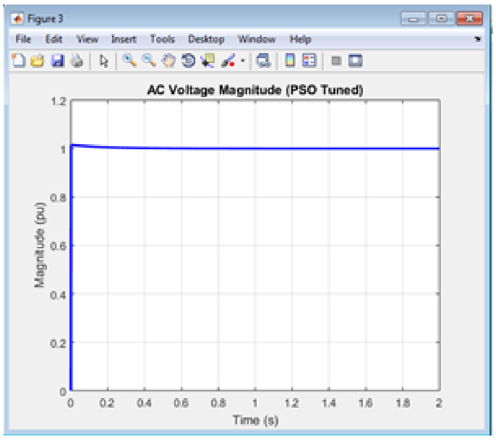


Fig. 11. AC voltage Filter impact.

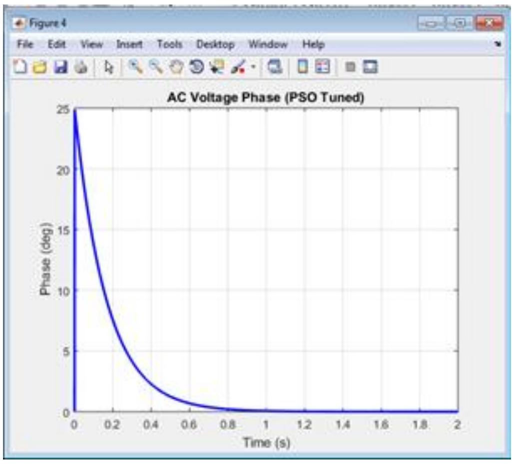


Fig. 12. Phase and Time Function.

VI. CONCLUSION

The implementation of PSO algorithm to solve the OPF problem is useful and worth of investigation. Moreover, PSO algorithm is easy to apply and simple since it has fewer number of parameters to deal with, comparing to other modern optimization algorithms. In addition, PSO algorithm is appropriate for solving the optimal power flow for systems that include variable generation resources. Using most effective control variables by applying sensitivity analysis reducing the space dimensions of PSO and hence improving the computing effort is needed for PSO algorithm and enhancing its performance, especially for large systems including many stochastic generation resources. The following could be included for further work: PSO algorithm needs some work on selecting proper parameters and it also needs more accurate mathematical description for its convergence. PSO can be applied in wind power bid marketing between electric power operators. In addition to operating cost, the environment effects and security or risk of wind power penetration can be included by using multi-objective models. Using singular value decomposition and pseudo-inverse techniques could be considered for further study to find the effective control variables.

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