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Total Transfer Capability Enhancement using Particle Swarm Optimisation Method

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Abstract

Competition in the electric power industry between sellers and buyers in power marketing poses new challenges for power system companies and researchers to find the best strategy for having beneficial energy trading. The technical challenges are related to the generation and transmission. Managing an effective operation can be provided by minimizing the operational cost, maximizing utilization of generators and transmission lines. However, power transmission systems are limited by the power transfer limits. With the recent trend towards deregulating power systems around the world, transfer capability computation emerges as the key issue to a smoothly running power market with multiple transactions. Total transfer Capability (TTC) is the basic measure for evaluating Available transfer capability (ATC).

This paper presents the calculation of TTC through an optimal power flow approach. The Particle Swarm optimization (PSO) method is selected to solve the TTC-OPF problem. Simulation Shows the increment in Area-wise Total transfer capability (TTC). IEEE 30 bus system is used for testing the proposed algorithm Capacitor allocation in power transmission systems have been considered to improve voltage profile.

Keywords: Electric Power Deregulation, Total Transfer Capability, Optimal Power Flow.

Introduction

The concept of competitive industries rather than regulated ones has become prominent in the past few years. Economists and political analysts have promoted the idea that free markets can drive down costs and prices thus reducing inefficiencies in power production. This change in the climate of ideas has fostered regulators to initiate reforms to restructure the electricity industry to achieve better service, reliable operation, and competitive rates. The U.S. electricity industry has reportedly taken the plunge towards deregulation. The Federal Energy Regulatory Commission (FERC), recognizing the centrality of open transmission to real competition, has mandated that transmission must be open to all comers. FERC, in conjunction with North American Electric Reliability Council (NERC), endorsed the exchange of transmission service information through Open Access Same-Time Information Network (OASIS). One of the main functions of the OASIS is to post Available Transfer Capability (ATC) information [1]

Available transfer capability (ATC) is the measure of the ability of interconnected electric systems to reliably move or transfer power from one area to another over all transmission lines or paths between those areas under specified system conditions. It is clear that ATC information is significant to the secure operation of deregulated power systems as it reflects physical realities of the transmission system such as customer demand level, network paradigm, generation dispatch and transfer between neighboring systems.

In order to obtain ATC, the total transfer capability (TTC) should be evaluated first where TTC is the largest flow through selected interfaces or corridors of the transmission network which causes no thermal overloads, voltage limit violations, voltage collapse or any other system problems such as transient stability. Other parameters involved in ATC calculations are the Transmission Reliability Margin (TRM) and Capacity Benefit Margin (CBM)[1].

It is becoming more and more important in the electrical industry, with the application to system security making it a very useful tool. The transfer capability is limited by a number of security constraints. To obtain an accurate value of the transfer capability of a system, contingencies may also need to be considered. The larger the transfer capability, the easier it becomes for a system to handle changes in its condition. The method is chosen due to its robustness and its ability to handle many practical constraints, explore all possible solutions, and find optimal solution within reasonable time.

Role of ATC

The Available Transfer Capability (ATC) is required to be reported on the Open Access same–time Information System (OASIS) to inform all energy market participants of the maximum power transfer capability in power systems. Therefore to improve the power system efficiency and economy, a good strategy for calculating ATC is required. Moreover the strategy can be used to predict ATC for the future transmission enhancement in power system planning. Available transfer capability calculation is important for electric power companies and energy buyers. ATC calculation not only determines the energy transfer bounds but it also determines the reliability of the system in unsecured situations.

Available Transfer Capability (ATC)

ATC is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses.

In general,

$$ATC = TTC – ETC.[1]$$

Total Transfer Capability (TTC)

It is the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner under a reasonable range of uncertainties and contingencies.

While determining TTC, system conditions, critical contingencies, system limits, parallel path flows and effects of non-simultaneous and simultaneous transfers are to be considered.[1] capability between the specified interfaces.

ATC ensures secure operation of the system ATC gives an idea of Congestion in the specified part of the system. ATC information can be used as a tool in transmission pricing. The binding constraint for ATC can be used in planning and network expansion. Computation of TTC need periodic updates of the following

System Limits

The transfer capability of the transmission network may be limited by the physical and electrical characteristics of the systems including thermal, voltage, and stability consideration. Once the critical contingencies are identified, their impact on the network must be evaluated to determine the most restrictive of those limitations [1]

Therefore, the Total Transfer Capability (TTC) becomes:

TTC = Minimum of {Thermal Limit, Voltage Limit, Stability Limit}

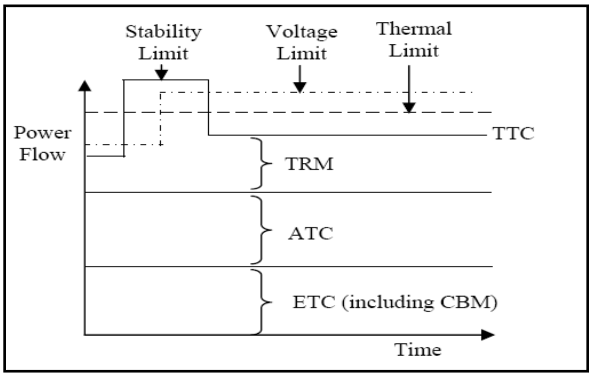

Fig 1: Limits on Power Transfer

Thermal Limits

Thermal limits establish the maximum amount of electric current that a transmission line or electrical facility can conduct over a specified time-period before it sustains permanent damage by overheating

Voltage Limits

System voltages and changes in voltages must be maintained within the range of acceptable minimum and maximum limits.

Stability Limits

The transmission network must be capable of surviving disturbances through the transient and dynamic time-periods following the disturbance. ll generators connected to the AC interconnected transmission systems operate in synchronism with each other.

Methodology Applied to Find TTC

PSO method is proposed to determine the optimal injecting of MVAR at selected locations for maximizing the total transfer capability (TTC)

The Particle Swarm Optimization is applied o solve the TTC OPF problem. The system has three areas with two generators in each area. Generators in each area are assumed to belong to the same owner and the loads belong to the same load serving entity. Transactions between different areas are investigated. Following simulations finds the area wise total transfer capability. Accurate identification of this capability will provide vital information for both planning and operation of bulk power market.

Using the proposed OPF based TTC method , initial load in area one is 84.5 MW.In the preceding step load at 7^{th} bus is incremented at the rate of 1 MW per iteration. Weak buses identified are bus no. 26 and bus no. 30.Optimal value of MVAR to be injected at bus no. 26 and bus no. 30 to improve TTC is found out using Particle swarm optimization.Fault analysis and Contingency are not considered.The bus voltages at 26^{th} and 30^{th} bus are checked. The permissible voltage magnitude range is taken as 1 p.u with +/- 5 % tolerance.

Then PSO program is executed which finds the optimal value of reactive power injections to be provided at 26^{th} and 30^{th} bus to improve the TTC in area 1.

The values for optimal reactive power injections generated from PSO are the substituted in the IEEE 30 bus system and the solution for power

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transfer is again generated. The new transfer capability with the injection is 122.5 MW.Overloading is done at a specific bus in a particular area and corresponding transactions are done.Computation of ATC starts with Load flow studies as it gives the pulse of the system.It is the prerequisite for every analysis on the power system.Load flow helps in continuous monitoring of current state of the power system. It also helps to examine effectiveness of alternative plans for future system expansion and to meet increased load demand.

The great importance of power flow or load-flow studies is in planning the future expansion of power systems as well as in determining the best operation of existing systems

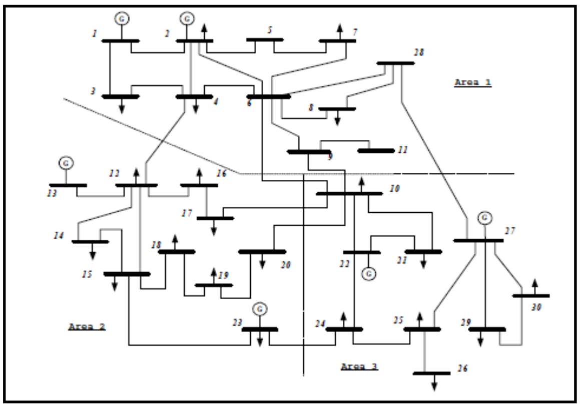

Fig 2: IEEE 30 Bus System

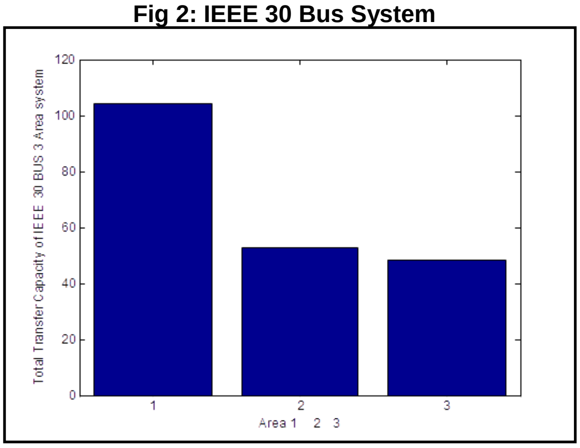

Fig 3: Area Wise Transfer Capability for Base Case

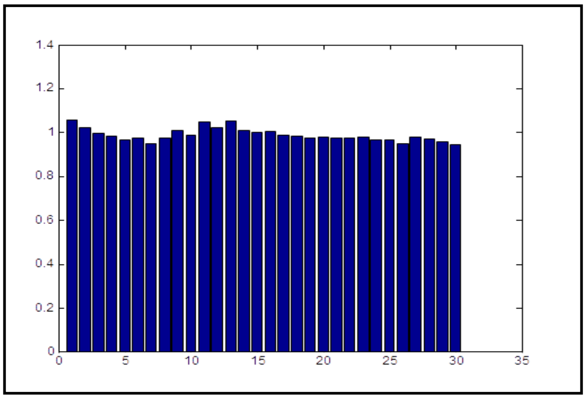

Fig 4: Bus Voltages for Base Case

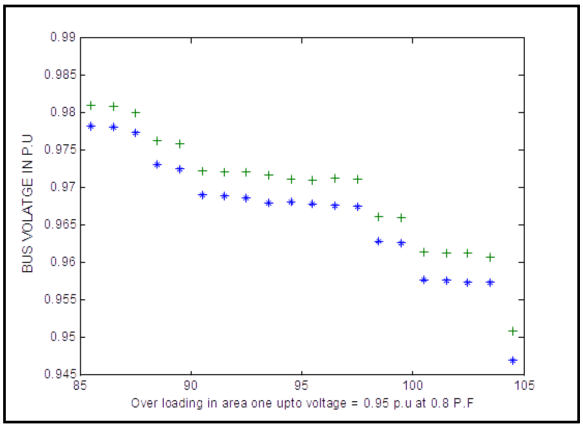

Fig 5: Bus Voltages in P.U. Transfer Obtained at Bus 26 and Bus 30 after Load Increments

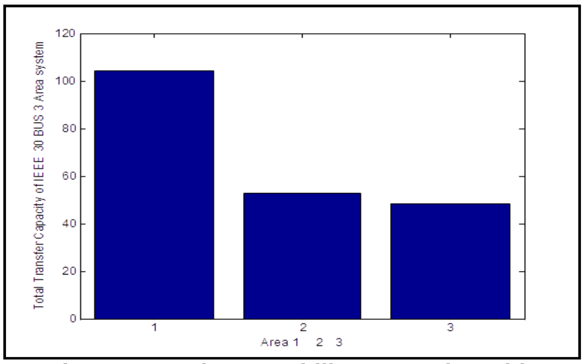

Fig 6: Area Wise Capability Area Wise with Permissible Load Increment

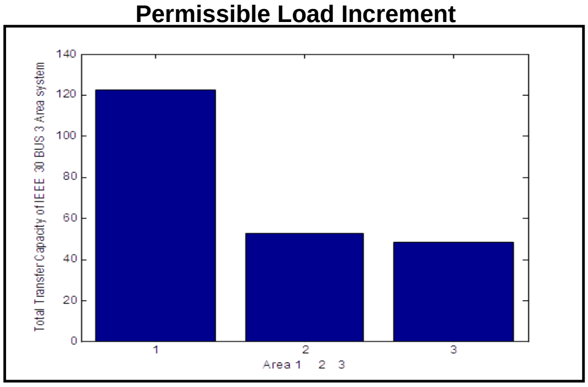

Fig 7: Area Wise Transfer Capability Area Wise after MVAR Injected at Bus No.26 and Bus No. 30

Particle Swarm Optimization

Similar to evolutionary algorithm, the PSO technique conducts searches using a population of particles, corresponding to individuals. Each particle represents a candidate solution to the power problem. In a PSO system, particles change their positions by flying around in a multidimensional search space until a relatively unchanged position has been encountered, or until computational limitations are exceeded. In social science context, a PSO system combines a social –only model and a cognition-only model. The social-only component suggests that individuals ignore their own experience and adjust their behavior according to the successful beliefs of the individual in the neighborhood. On the other hand, the cognition-only component treats individuals as isolated beings. A particle changes its position using these models.

It is inspired from the nature social behavior and dynamic movements with communications of insects, birds and fish. Uses a number of agents (**particles**) that constitute a swarm moving around in the search space looking for the best solution Each particle in search space adjusts its “flying” according to its own flying experience as well as the flying experience of other particles.

The advantages of PSO over other traditional optimization techniques can be summarized as follows:

1. PSO is a population-based search algorithm (i.e. PSO has implicit parallelism). This property ensures PSO to be less susceptible to getting trapped on local minima.
2. PSO uses payoff (performance index or objective function) information to guide the search in the problem space. Therefore, PSO can easily deal with non-differentiable objective functions. Additionally, this property relieves PSO of assumptions and approximations, which are often required by traditional optimization models.
3. PSO uses probabilistic transition rules and not deterministic rules. Hence, PSO is a kind of stochastic optimization algorithm that can search a complicated and uncertain area. This makes PSO more flexible and roust than conventional methods.

Fig 8: Results for Area Wise TTC

Case Wise Results	Area 1 in MW	Area 2 in MW	Area 3 in MW
Initial transfer in MW	84.5	52.7	48.5
Tie lines connected load in other 2 areas kept constant and load in the respective area is increased but MVARS are not injected.	104.5	69.7	51.5
Tie lines connected, load in other 2 areas kept constant and load in the respective area is increased and MVARS are injected.	122.5	121.7	56.5

PSO Alghorithm

The basic elements of the PSO techniques are briefly stated and defined as follows:

1. **Particle X (t):** It is a candidate solution represented by a k-dimensional real-valued vector, where k is the number of optimized parameters. At time t, the ith particle Xi(t) can be described as Xi (t)= [xi, 1(t); xi, 2(t);……;xi,k(t)].
2. **Population:** it is a set of n particles at time t.
3. **Swarm:** it is an apparently disorganized population of moving particles that tend to cluster together while each particle seems to be moving in a random direction.
4. **Particle Velocity V (t):** It is the velocity of the moving particles represented by a k-dimensional real-valued vector. At time t, the ith particle Vi (t) can be described as Vi (t)=[vi,1(t); vi,2(t); ……;vi,k(t)].
5. **Inertia Weight w(t):** it is a control parameter that is used to control the impact of the previous velocity on the current velocity. All the control variables transformer tap positions and switch-able shunt capacitor banks are integer variables and not continuous variables. Therefore, the value of the inertia weight is considered to be 1 in this study.
6. **Individual Best X* (t):** As the particle moves through the search space, it compares its fitness value at the current position to the best fitness value it has ever attained at any time up to the current time. The best position that is associated with the best fitness encountered so far is called the individual best X* (t). Individual best updating: each particle is evaluated and updated according to the update position.
7. **Global Best X** (t):** It is the best position among all of the individual best positions achieved so far.
8. **Stopping Criteria:** These are the conditions under which the search process will terminate. In this study, the search will terminate if one of following criteria is satisfied:

• The number of the iterations since the last change of the best solution is greater than a pre-specified number.

• The number of iterations reaches the maximum allowable number.

In a PSO algorithm, the population has n particles that represent candidate solutions. Each particle is a k-dimensional Real-valued vector, where k is the number of the optimized parameters. Therefore, each optimized parameter represents a dimension of the problem space.

Simulation Results and Discussion

The objective is achieved by finding the optimal values of reactances required to be injected at 26^{th} and 30^{th} bus. A feature of the system is large power transfers from the top area of the bottom area over a long transmission distance. This makes it appropriate to increase the transfer limits. The system has six generators, 30 buses and 7 tie lines. Two independent reactive compensators Xc1 and Xc2, are to be located at bus 26 and bus 30 respectively.

Conclusion

A new formulation for OPF to calculate the Total Transfer Capability TTC is reported in this paper. The objective function is the load increase on specific source and sink nodes. The thermal limits of transmission lines, voltage bounds of buses, and upper and lower limits of generator power are considered as well as load flow equations.

The Particle swarm optimisation method is extended for TTC calculation. An algorithm has been developed and tested on the IEEE 30-bus system. Computer results show that the proposed method is very effective, and with good convergence characteristics as well, in determining TTC.

The Main Conclusions of the Paper are

The proposed PSO-OPF based TTC algorithm works well in determining TTC between different areas subject to system operation limits.

In this paper PSO-OPF is developed to solve the optimal reactive requirement to improve TTC.

The results are obtained using PSO illustrates that the pro-posed algorithm is simple and practical. This method is compatible with the new competitive market structure and economic efficiency can be achieved. The algorithm is tested on an IEEE-30 bus system.

Appendix

IEEE 30 Bus System Data

Total load of area 1 = 84.5 MW

Total load of area 2 = 56.2 MW

Total load of area 3 = 48.5 MW

References

1. Transmission Transfer Capability Task Force, “Available Transfer Capability Definitions and Determination”, North American Electric Reliability Council, Princeton, NJ, June 1996.
2. M. Shaaban, Y. Ni, H. Dai and F. Wu, “Considerations in Calculating Total Transfer Capability”, Proc. Of the International Conference on Power System Technology, Beijing, Vol. 2, pp. 1356-1360, August 1998.
3. S. S. Rao, “Engineering Optimization: Theory and Practice”, John Wiley & Sons, 3 rd edition, 1996. [8] Powertch Labs Inc., “Voltage Stability Analysis Program (VSTAB) User’s Manual”, Prepared for EPRI, USA, 1997.
4. Transfer Capability Computations in Deregulated Power SystemsMohamed Shaaban (St. M. IEEE) Yixin Ni (S. M. IEEE) Felix F. Wu (Fellow, IEEE)Center for Electrical Energy Systems Department of Electrical and Electronics Engineering, Hong Kong Proceedings of the 33rd Hawaii International Conference on System Sciences - 2000
5. G. C. Ejebe, J. Tong, J. G. Waight, J. G. Frame, X. Wang and W.F. Tinney, “Available Transfer Capability Calculations”, *PE-321-PWRS-0-10-97.*
6. “TTC and CBM Calculation of IEEE-30 Bus System” Ms. Priti Kachore Dept. of EE, G. H .Raisoni College of Engineering RTM Nagpur University Nagpur, India Prof. Mrs. M. V. Palandurkar Dept. of EE, G. H. Raisoni College of Engineering RTM Nagpur University Nagpur, India Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09