Title of Research:

**POWER SYSTEM STEADY STATE STABILITY EMBEDDED WITH MULTIPLE WIND TURBINES THROUGH CO-ORDINATED OPERATION OF UPFC-HVDC LINK.**

1. **Objectives:**

The main objective of this research work shall be on the steady state stability of the power system and performance of multiple wind turbines. As a case study, real values of wind shall be taken with following research objective.

1. Assessment of wind speed under different climatic conditions.
2. To incorporate optimization technique i.e. Ant colony algorithm to control pitch angle of wind turbine.
3. To incorporate a HVDC-link for transmitting wind power to grid by using Unified Power Flow Controller (UPFC).
4. Analysis of proposed system with multi-line, multi-bus, IEEE system.
5. To evaluate steady state performance of power system in terms of active and reactive power flow of a transmission line.

Ant Colony Algorithm will be used as an optimizing technique to extract maximum wind power by controlling pitch angle and UPFC in Co-ordination with HVDC link will be used to control active and reactive flow of power in a transmission line.

1. **METHODOLOGY:**

**The work will be carried out in the following steps:**

The simulation of power system for the **“Power System Steady State Stability Embedded with Multiple Wind Turbines through Co-Ordinated Operation of UPFC-HVDC Link”** shall be earned as given below:

1. Single wind turbine generator connected to single bus through HVDC shall be simulated and tested. Then the multiple turbines connected to single bus system through HVDC shall be simulated.
2. Optimization technique will be employed to extract maximum power through control of λ, β (Pitch) angle of wind turbine for both single turbine and multiple turbine connected to single bus system.
3. The optimized wind power injected through HVDC link for single bus system shall be extended to multi-bus IEEE system.
4. The UPFC (Unified Power Flow Controller) will be simulated and embedded in single bus and multi-bus system. The active and reactive power control and analysis will be carried out.
5. The power system performance shall be investigated in terms of power quality, power congestion and stability.
6. The results obtained will be presented in graphical and tubular forms (Which ever feasible.)
7. **Literature Review:**

As discussed the impact of non-renewable energy resources is needed into the present grid. Wind energy which is expected to be a promising alternate energy source, can bring new challenges when connected to the power grid such as power generated from wind energy is always fluctuating in nature due to environmental conditions [1]. Fluctuation in wind creates lot of problems in the generated power delivered by the wind turbines to the electricity network. The problems encountered are cited by the various authors are as follows:

**2.1 Power quality:**

The fluctuation of wind causes fluctuations in the power delivered by the wind farm to the electricity network. Therefore, the development of systems to improve voltage stability, frequency stability and power quality is an important line of research in the wind power field.

The power quality issues and its consequences on the consumer and electric utility are presented. It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system [2].

Renewable energy sources specifically wind and solar with the most potential for significant penetration in the near term. Future power transmission and distribution network with a high percentage of renewable resources may have more generation sources than existing networks: Scalability or Power quality would be a significant factor [3]. Oren [4] discussed the impact that massive integration of wind power will have on the power system in terms of efficiency, operational reliability, economic consequences and environment outcomes.

**2.2 Voltage Instability:**

Impact of different parameters such as temperature, solar irradiance and load changes on voltage stability had been discussed [5]. In the grid impact studies of wind power integration, the voltage stability issue is a key problem because a large proportion of existing wind farms are based on Fixed-Speed Wind Turbines (FSWTs) equipped with simple induction generators [6].

Voltage stability depends on how the variations in Q and P affect the voltages at the load buses. The influence of reactive power characteristics of devices at the receiving end is more apparent in a QV relationship. The sensitivity and variation of bus voltages with respect to reactive power injections or absorptions discussed in [7].

**2.3 Rotor Angle Stability:**

For a multi-machine power system the angular separation between synchronous generators is an important factor to maintain transient stability, since when the Maximum Rotor Angle Difference (MRAD) between two generators or a group of generators exceeds 180°, there would be a high probability of losing stability, because of rapid voltage drop at intermediate points of the network, inflicting voltage instability [8].

However, regardless of the challenges of large scale wind power integration, after 30 years of rapid technological development and owing to current economic, political and environmental circumstances, wind power is poised to become a mainstream energy source capable of supplying bulk quantities of power to the electricity grid.

**2.4 Potential Assessment of wind energy on large scale:**

Integrated storage system had been applied to isolate the grid from wind speed disturbances, as well as the ability to actively absorb wind energy during severe and sustained grid-side fault conditions [9].

Dynamic models of double fed induction generators to investigate the behaviour of different converter control and protection strategies of the back–to-back IGBT-based converters during grid fault was used in [10].

Lannoye et al. [11] highlighted the importance of transmission networks when considering the flexibility of a power system as the penetration of variable generators increase. The methodology presented enables power system planners to quantify the flexibility capabilities of a system by determining the maximum realizable flexibility which can be deployed at a time.

2.5 **Optimizing Wind Power:**

Wind turbines are expensive to build and maintain. The wind field from which they generate power is also the source of large fatigue loads on the turbine, which create structural wear and tear, increasing maintenance costs and decreasing the operational lifetime of the turbine. Rotor angle control or pitch control is one of the most ubiquitously used control techniques to regulate the output power of wind turbine generators. The methods proposed by many authors are described as follows:

An evolutionary computational approach for optimization of power factor and power output of wind turbines had been presented. An evolutionary strategy algorithm solved the data-derived optimization model and determined optimal control settings [12]. Belghazi et al. [13] compared genetic algorithm technique with conventional pitch angle control strategies. Results showed that GA controller can achieve better control performance than conventional pitch angle control strategies.

Ramakrishnan et al. [14] described the various components in a pitch controlled wind energy system and discussed the response of the pitch-controlled system to wind velocity variations. The aerodynamic power control for the variable speed wind turbine can limit the power injected into the turbine by reducing the angle of blades.

The maximum power estimation at various windmill speeds (rpm) of the trained ANN in determined reference speeds was analysed. The zero crossing points of the phases were determined by a digital signal peripheral interface controller and the system was operated according to the triggering angles obtained from the ANN-based control algorithm at the maximum power points [15].

To optimize energy consumption minimization of wind system ant colony algorithm was used. The improved ant colony algorithm solved the defect of directly deal with continuous optimization problem by discretizing the solution space of continuous function [16]. Blade parameters were optimised to minimize the cost of energy of wind turbine rotor using Ant Colony Optimization approach [17].

Pouladi et al. [18] presented a method based on opposition based ant optimization (OACO) which analysed multiple candidates for selection of optimum wind farm for establishment.

Wang et al. [19] discussed an Ant Colony System (ACS) based optimization procedure to assess the power-generating system adequacy including wind power integration since ACS had shown to be an outstanding discrete optimizer.

2.6 **Integrated AC/DC Transmission System using FACTS and HVDC Links:**

In order to promote the integration of wind farms into the electrical network, Flexible AC Transmission Systems (FACTS) and HVDC links are widely used [20]. Methods used by many authors for integration of wind power on large scale using FACTS and HVDC links are as follows:

VSC-HVDC were used to integrate AC/DC parallel connected wind farm. High voltage direct transmission of voltage source converter (VSC-HVDC) had merits to supply passive network, which cannot only quickly transmit power but also can flexibly compensated reactive power to grid-connected system to stabilized [21-22]. STATCOM based control scheme had been used for power quality improvement in grid connected wind generating system and with non-linear load [26-27].

Wei et al. [28] developed a new method to analyse voltage stability for AC/DC systems with VSC-HVDC. Results indicated that the constant AC voltage control of VSC converter was superior to other control modes in voltage stability.

A 3 MW wind farm consisted of ten 300 kW PMIGs were simulated to demonstrate the dynamic operation of the system. A model of wind farm system with several PMIGs connected to a single voltage source converter were presented in [29].

Ramesh et al. [30] identified the improved power transmission capability through control scheme and did comprehensive analysis for a Unified Power Flow Controller (UPFC) on the basis of theory and computer simulations. UPFC improves the system performance under the transient and the normal conditions.

Saxena et al. [31] proposed the application of Unified power flow controller for damping power system oscillations with an additional Power Oscillation Damping (POD) controller.

Ghahnavieh et al. [32] presented the optimal control mode and settings of UPFCs. A two-source power injection model was used for UPFC and the impact of UPFC control modes and settings on reliability indices were investigated.

Sebastian et al. [33] analysed real, reactive power and voltage balance of the unified power flow controller system. Experimental works had been conducted to verify the effectiveness of the UPFC in power flow control in the transmission line. Experiments had been performed in which both the shunt converter and series converter had been built as a three-phase PWM converter with IGBT as the power device.