Becchi, Rouet, Stora and Tyutin (BRST) method is one of the most powerful techniques of quantization for the system with constraints. BRST quantization is based on the BRST transformations which are symmetry of the theory. BRST transformations are characterized by an infinitesimal, anti-commuting, global parameter. Such transformations are nilpotent in nature. Because of these properties, the BRST transformation is extremely useful in studying unitarity, renormalizability and other aspects of different effective theories in particle physics. Other nilpotent transformations also play important roles in studying different gauge theories. These transformations are obtained from BRST transformations by interchanging the ghost and anti-ghost fields and known as anti-BRST transformations.

There are several methods to construct BRST transformation. One of these methods is field/anti-field formalism also called Batalin-Vilkovisky (BV) formalism or Lagrangian BRST formalism. This method is more general than usual Faddeev-Popov method and used for wider class of gauge theories (gauge theories with reducible/irreducible gauge algebra). Another method for constructing BRST transformation is Hamiltonian BRST formalism also called Batalin-Fradkin-Vilkovisky (BFV) formalism. This method is used to construct BRST transformation of constrained systems.

Recently, the concept of finite field dependent BRST (FFBRST) transformations have been introduced by generalizing usual BRST transformations. The parameters in such transformations are finite field dependent and anti-commuting. The FFBRST transformations are also symmetry of the effective theory and nilpotent. However, the Jacobians of such transformations are not unity because it involves finite parameter. Therefore the path integral measure is not invariant. This non-trivial Jacobian leads to several new results.

FFBRST transformations have many applications in gauge field theories. A correct prescription for the poles in the gauge field propagators in non-covariant gauges have been derived by connecting effective theories in covariant gauges to the theories in non-covariant gauges by using FFBRST transformation. The divergent energy integrals in Coulomb gauge are regularized by modifying time like propagator using FFBRST transformation.

My thesis work is primarily focused on BRST and FFBRST of various field theoretic models.

The entire thesis has been divided into seven chapters as given below:

In Chapter I we will provide basic information and general introduction of the research work. First we will talk about how BRST transformations came into picture. Then
we will discuss their importance in the physical theories. Further we will give introductory idea of our research work done during this period.

The main objective of the chapter II is to provide the basic mathematical tools and techniques related to BRST transformation to prepare the necessary background relevant to this thesis. First we will discuss BRST Transformations in Lagrangian formalism where we will discuss BRST quantization of non-Abelian Yang-Mills theory. Later we will discuss field-antifield formalism or Batalin-Vilkovisky (BV) formalism. Then we will discuss Hamiltonian formalism or Batalin-Fradkin-Vilkovisky (BFV) formalism, Dirac Constraint analysis and Batalin-Fradkin-Fradkina-Tyutin (BFFT) technique. Atlast we will discuss FFBRST Transformations.

In Chapter III, we apply a generalized Becchi-Rouet-Stora-Tyutin (BRST) formulation to establish a connection between the gauge-fixed SU(2)YangMills (YM) theories formulated in the Lorenz gauge and in the Maximal Abelian (MA) gauge. It is shown that the generating functional corresponding to the FaddeevPopov (FP) effective action in the MA gauge can be obtained from that in the Lorenz gauge by carrying out an appropriate finite and field-dependent BRST (FFBRST) transformation. In this procedure, the FP effective action in the MA gauge is found from that in the Lorenz gauge by incorporating the contribution of non-trivial Jacobian due to the FFBRST transformation of the path integral measure. The present FFBRST formulation might be useful to see how Abelian dominance in the MA gauge is realized in the Lorenz gauge.

In Chapter IV, we investigate all possible nilpotent symmetries for a particle on torus. We explicitly construct four independent nilpotent BRST symmetries for such systems and derive the algebra between the generators of such symmetries. We show that such a system has rich mathematical properties and behaves as double Hodge theory. We further construct the finite field dependent BRST transformation for such systems by integrating the infinitesimal BRST transformation systematically. Such a finite transformation is useful in realizing the various theories with toric geometry.

Further we develop BRST symmetry for the first time for a particle on the surface of a torus knot by analyzing the constraints of the system. The theory contains 2nd-class constraints and has been extended by introducing the Wess-Zumino term to convert it into a theory with first-class constraints. BFV analysis of the extended theory is performed to construct BRST/anti-BRST symmetries for the particle on a torus knot. The nilpotent BRST/anti-BRST charges which generate such symmetries are constructed explicitly. The states annihilated by these nilpotent charges consist of the physical Hilbert space. We indicate how various effective theories on the surface of the torus knot are related through the generalized version of the BRST transformation with finite field dependent parameters.
In Chapter V, we show how Weyl degree of freedom can be introduced in the Nambu-Goto string in the path-integral formulation using the re-parametrization invariant measure. We first identify Weyl degrees in conformal gauge using BFV formulation. Further we change the Nambu-Goto string action to the Polyakov action. The generating functional in light-cone gauge is then obtained from the generating functional corresponding to the Polyakov action in conformal gauge by using suitably constructed finite field dependent BRST transformation.

In Chapter VI, we consider Polyakov theory of Bosonic strings in conformal gauge which exhibits conformal and ghost number anomaly. We show how these anomalies can be removed by connecting this theory to that of in background covariant harmonic gauge by using suitably constructed finite field dependent BRST transformation.

In Chapter VII, we will present a brief summary of our entire research work carried out during this research period.
List of Publications:

1. *Maximal Abelian Gauge and Generalized BRST transformation*

2. *Double Hodge Theory for a Particle on Torus*

3. *BRST Symmetry for Torus Knot*

4. *Weyl Degree of Freedom in Nambu-Goto String Through Field Transformation*

5. *BRST Quantization on Torus Knot*

6. *Conformal to Harmonic Gauge for Bosonic Strings*
   V. K. Pandey and B. P. Mandal, accepted for publication in Euro Phys. Letters.