POWER SYSTEM DYNAMICS AND CONTROL

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INTRODUCTION

Electric power system comprises components and systems like Generators, transformers, transmission lines and distribution networks, each of which is liable to be affected by insulation failure, due to over voltage or over load. They may also fail under normal service conditions owing to aging or poor quality of material or of manufacturing process. The conductors comprising the transmission and distribution network are also exposed to the elements like lightning, rain, wind, snow etc. which can cause short circuit faults or otherwise damage supporting structures. Insulation failure due to any of these causes lead to trip outs and other disturbances which at times be severe enough to culminate in wide spread power outages or black outs.

Power interruptions are equally unwelcome to every consumer but its effect is particularly severe on consumers like railways, hospitals, and other industries engaged in production of ferrous and non-ferrous metal products, chemicals and petro-chemicals, semi-conductors etc., all of which involve critical processes. The consequences can be human suffering and financial losses running into several millions.

There are a number of measures available to minimize the possibility of occurrence of black outs, or, if one does occur, to mitigate its adverse effects on important class of consumers. TCE has been in the forefront in devising solutions to help consumers keep black outs at bay. Some of the solutions are outlined below.

1. ISLANDING AND LOAD SHEDDING

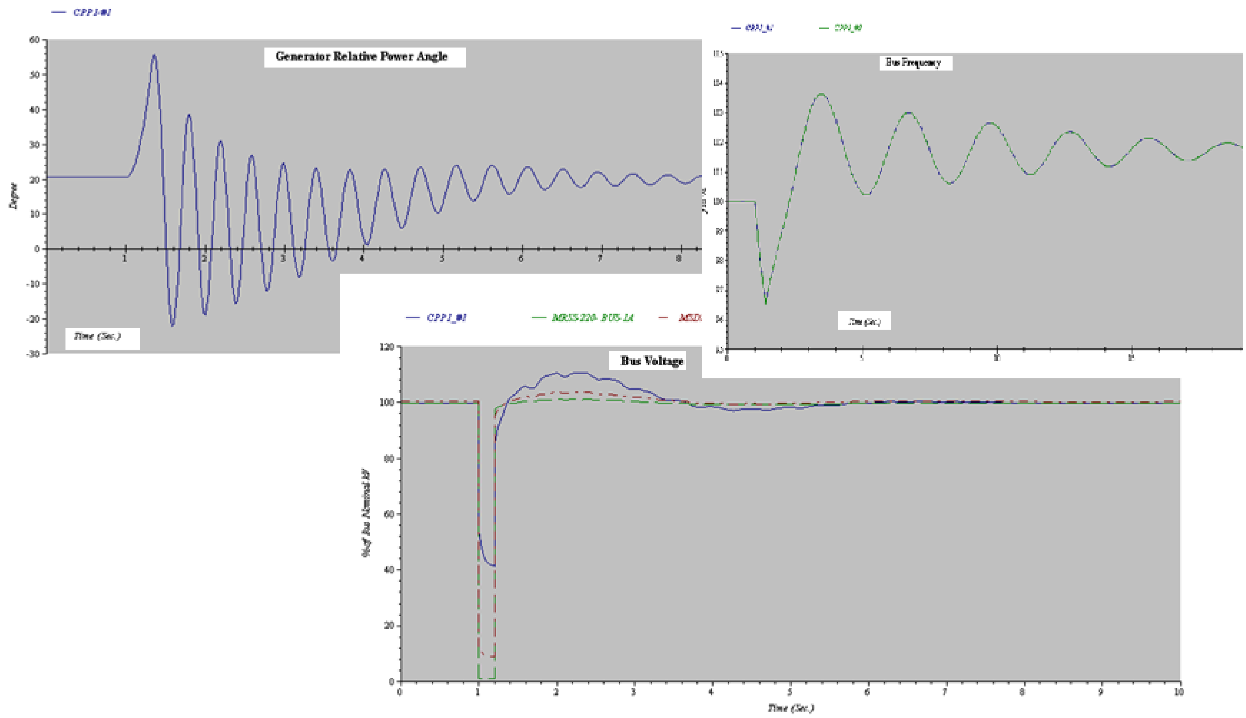
PROTECTION OF POWER SUPPLY SYSTEMS AGAINST BLACKOUT

Power system blackouts are due to cascading failure of a larger section of the electrical network involving generators, transformers or transmission line etc., More precisely, they are generally caused when short circuit faults, particularly involving busbars in large power plants or receiving stations, are not cleared because of failure of primary protections, requiring back-up protection to operate, entailing delay. This delay increases possibilities of some generating unit losing stability and tripping out. Black outs may also be triggered due to the loss of a transformer or a transmission line carrying bulk power leading to the overloading of sections of power system which may trip in consequence; or due to tripping out of a large generating unit, when spare capacity is not available. These events can lead to a cascading effect, particularly in grids which have been predisposed to enter unstable region either because of overloading of grid as a whole resulting in low frequency and low voltage. A sound solution which minimizes the possibility of black outs is to build in sufficient redundancy in the power generation and transmission system but its implementation calls for careful planning, investment of huge capital, and resolution of issues relating to environment, land acquisition, adequate fuel supply arrangement, etc.

Less expensive and easily implementable solutions will mitigate the adverse effects of black outs that is beneficial to particular class of consumers such as industries employing critical manufacturing processes, or large cities and towns, are available and have been engineered by TCE.
Generally all process plants will have captive generation stations which meet part of their power requirement while the balance of power is drawn from the grid. In the event of any grid disturbance,

schemes have been developed to quickly isolate the process plant electrical system from the Grid. A typical scheme envisaged for such plants operates in two stages: in the first stage, called 'islanding', disturbances in the grid which can potentially lead to blackouts are detected in an incipient stage and the plant along with its captive generating station is disconnected from the grid. The second stage, known as 'load shedding', checks the adequacy of the power produced by the captive generating station to meet the requirement of the plant and, in the event that it is insufficient to supply to all the loads, disconnects the non-critical and less critical loads, as required, so that the available power is supplied to the most critical loads. The balance between the internal generation and plant loads is checked dynamically in real time, and just so much of load is quickly shed as is necessary to match the available power with load. In the absence of islanding and load shedding schemes, plant and machinery involved in critical processes can be adversely affected, resulting in their being damaged and shut down for considerably long durations for repair and restoration. The consequent loss of revenue runs into hundreds of millions.

The design of such schemes require accurate modeling of the entire systems in a computer simulation study to determine the speed and efficacy of the scheme in saving the captive system of process plants under different types of faults at locations both within and outside the system.



Frequency, Rotor Angle & Voltage Response of System following Grid Islanding and Load shedding

A slightly different kind of islanding and load shedding scheme is provided for large cities and towns having power generating plants that operate in synchronism with the grid at large, and supply surplus power to state and national grids, or draw power from the grid to make up for the short fall in their own generation. In the event of disturbance in the grid, the generating units together with the loads of the city are disconnected from the grid. The difference between generation and the loads of the city are computed, and depending upon which is greater, either the excess load is shed or excess generation is reduced and the balance between the two is quickly restored.

The response time of these islanding and load shedding schemes is in the order few milli seconds, which is short enough to prevent the spreading of disturbances to the islanded systems. Several safety features are incorporated to minimize the possibility of their mal-operation or non-operation. It is indeed possible, by design, to make these schemes virtually fail-safe.

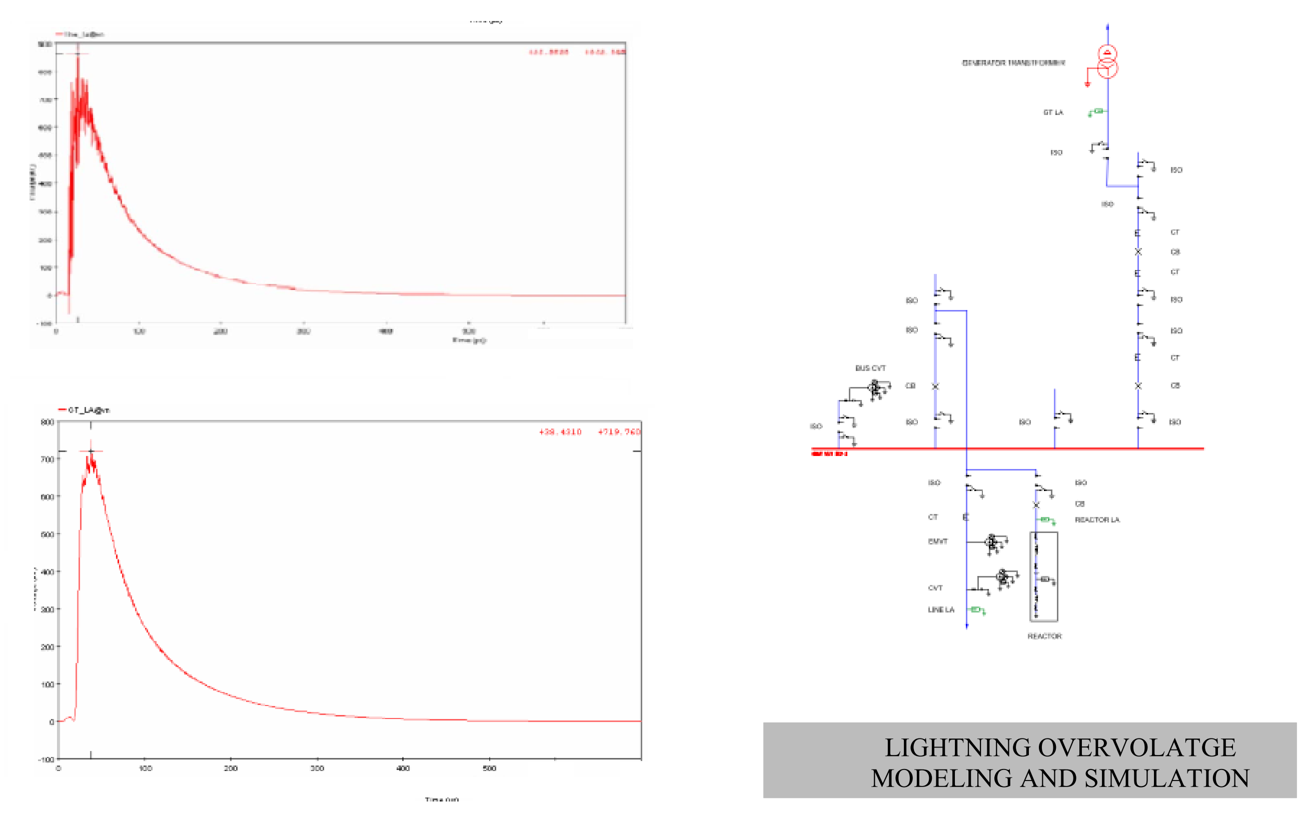
2. INSULATION CO-ORDINATION

PROTECTION OF POWER SYSTEMS AGAINST FAST FRONT TRANSIENT OVER VOLTAGES

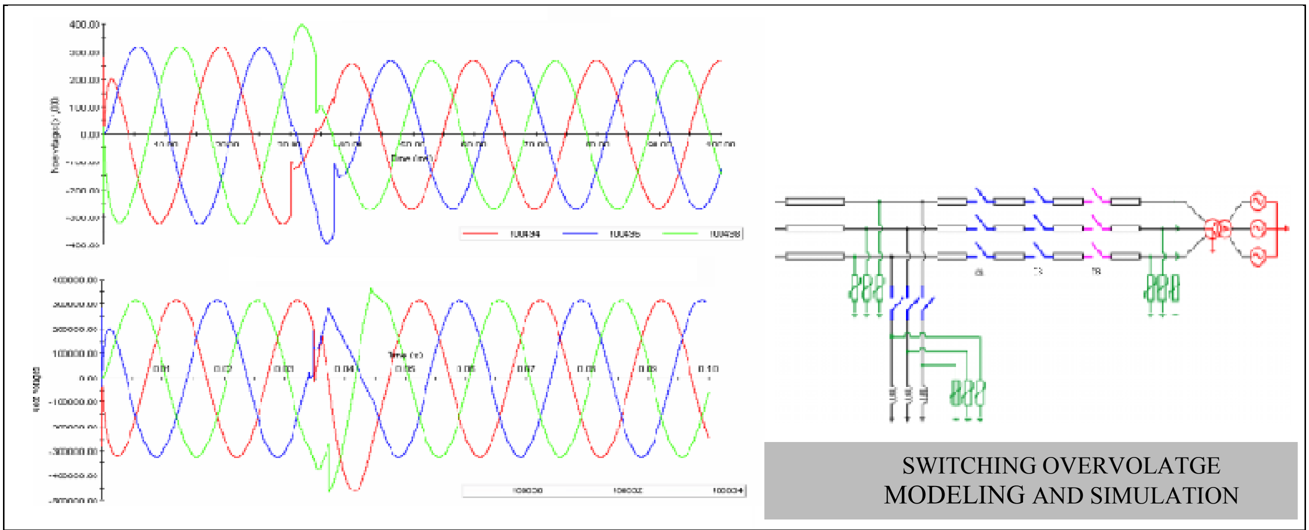
Electronic and electrical equipment ranging from house hold devices like TV sets, microwave ovens, personal computers etc., to extra high voltage devices such as power transformers, instrument transformers, circuit breakers used in bulk power transmission are all subject to damage when exposed to over voltages several times higher in magnitude than the rated voltage at which they are designed for. These over voltages arise due to factors like lightning or high frequency electromagnetic radiation which is external to the electrical system, or they are generated internally due to switching operations within the system. The study of origin and nature of transient over voltages, and devising remedies against their ill-effects, is therefore an important branch of High Voltage engineering. An event such as a lightning strike can cause extensive damage to structures and break-down of insulation of electrical power equipment causing expensive power outages.

Insulation coordination studies are aimed at determining the magnitude of over voltages to which insulators used in transmission lines, and transformers and gas insulated switch-gear in receiving stations, are subjected to. This information helps in devising the optimal protective counter measures to prevent disastrous failures. The study involves modeling the power system in which normal impedances are replaced with 'surge impedances'. The accuracy of the result is directly dependent upon the precision of modeling.

TCE employs advanced software tools to accurately determine different type over voltages at various locations of interest in complex power networks which will aid in devising appropriate protections for these installations. Several over voltage studies have been carried out by TCE to access the severity of over voltages due to lightning surge and to protect the equipment from surges and transients on incoming power line to prevent equipment damage and costly operational down time and loss of data.



LIGHTNING OVERVOLATGE
MODELING AND SIMULATION



SWITCHING OVERVOLATGE
MODELING AND SIMULATION

The voltage wave forms generated by the computer programme clearly show the over voltages at select locations and establish whether additional protection needs to be provided. They also show the effectiveness of such protection.

ABOUT AUTHOR

Mr. S Jagadish holds a degree in electrical engineering. He has nearly forty years of experience in the fields of electrical power system protection, control and studies covering load flow, stability, Islanding-Load shedding, over voltages, relay co-ordination, etc. He has made significant contributions to commissioning and operation of electrical systems while working with National Thermal Power Corporation (NTPC). He later joined Tata Consulting Engineers where he was engaged in engineering of large power plants, particularly in the areas of protection, control and power system studies. He has authored several investigative reports on the incidents of black out and other types of system failure in industrial power supply systems. He is at present with Tata Consulting Engineers in the capacity of consultant.

Ms. Priyanka Swain holds a degree in electrical engineering. She has six years of experience in the fields of electrical power system protection, control and studies covering load flow, short circuit, transient stability, Islanding-load shedding, power quality, insulation coordination, relay co-ordination etc. In her past assignment, she has carried out numerous studies for various process Industries including Petro-chemical, Steel and Metal etc., and was also involved in State and Central Transmission & Distribution Grid networks strengthening studies. She later joined Tata Consulting Engineers, where she was engaged in power system study, control, protection for large power plants and various process industries with captive generation.