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Dynamic Models For Teaching And Research In Electrical Engineering And Management Of Power

Ramleela Khare[1], Filipe Rodrigues E Melo[2]

[1]Director Research, The MRPC Company, Hyderabad, India

[2]Assoc. Professor Commerce, St. Xavier's College Of Arts, Science & Commerce, Goa

ABSTRACT

The author presents in this paper several dynamic models that he has developed for teaching and research related to electrical power systems and management of power, automation and reliability of operation. These dynamic models are low cost and helpful in conceptualizing the theory and practice of technology in the listed areas. Most often the research on technology requires a dynamic model to generate a data for enhancing understanding or concluding the observation of the research to arrive at the right conclusions. The purpose of making dynamic models of a power grid system was to make firsthand detailed study of various aspects related to economic management of power transmission. The experimental model developed used remote Supervisory Control and Data Acquisition (SCADA) using wireless methods and computer software for convenience and better management.

Keywords: lab dynamic model, teaching electrical, research, simulation

1. INTRODUCTION

THE MODELS DEVELOPED

[1] and [8] Ramleela Khare , Filipe Rodrigues E Melo describe in their paper "Automation in Energy Management Systems" the latest development in SCADA automation which includes devices, techniques and security of the network drawn from various international journals extending over a period of 20 years and attending several seminars. It includes master hardware and software developed by the author for data acquisition and displays the data of MFM on the computer software. SCADA Architecture is also provided for water distribution and storage plant.

[2] Ramleela Khare, Filipe Rodrigues E Melo give details of the "AC Network Analyzer—A Dynamic Benchmark Model for Experimental Study" that they have developed for electrical power system laboratory for experiments. Though low cost, it is versatile equipment, for making various studies related to power transmission of interconnected grid network.

Various experiments conducted using the AC Network Analyzer reflects on *how the power system network can be inter-connected for a reliable economic and* *efficient performance.* How the power flow will be affected by addition of a generator or a transmission line and load and how the grid will be affected incase of outage of the transmission line, generator and load. This paper also contains the data and method of evaluation using the AC Network Analyzer for the study of faults on transmission or generator bus. How much fault current will flow and what should be the setting of the relays and the circuit breaker in isolating the fault affected system (line or generator).

The usage of the analyzer does not require any technical expertise. It is self explanatory and it is failure safe equipment protected from wrong connections.
The model works with scaled down base values of the real system and the *data on the model can be converted into the parameters of voltage, current and power of the real system by multiplying with base values.* In this case for example 20 V bus voltage and 10 mA current on the model represent 200 KV, 20 MVA and 100 Amps of power of the real system.

This dynamic AC Network Analyzer model is an important *teaching aid* in laboratory of electrical power engineering in engineering colleges and electrical utility training centers. The author had the privilege of delivering seminars on this equipment at both, the electrical department of a university and a utility training center.

[3] Ramleela Khare, Filipe Rodrigues E Melo in their paper "Economic and Efficient Management of Transmission and Control of Electrical Power – Design of A SCADA Power System Monitor" describe the details of the dynamic model of Power System Monitor and the experiments conducted on it for economic management of power. The requirement for efficient and economic management of electrical system has promoted research in implementing innovative technologies in power generation and transmission. The model includes SCADA and UPFC (Unified Power Flow controller) (FACTS) Flexible Alternating Current Transmission System are electronic devices for control of power flow in transmission network, enabling transmission line to be loaded to its full capacity enhancing utilization and reliability of transmission lines resulting into financial benefit of additional sales of power.

For economic management of transmission of power UPFC is a crucial device for control to optimize the power transferred through transmission line. Therefore, it is one of the primary factors in the economic management. The simulation of UPFC device on this model of "Power System Monitor" provided dynamic control of voltage, phase angle, impedance, active and reactive power flow in transmission lines. Division of power was achieved in parallel lines to their optimized capacities and enhanced transfer of power in lines by 20% while maintaining reliability of system operation through the use of UPFC device.

Loss of power in transmission line on the model was obtained by taking the difference of the reading of power displayed by the multifunction meter (MFM) at the sending end and receiving end of the transmission line. It was observed that this *power loss was reduced as the impedance of the transmission line was countered by using a series capacitance* (compensation) and exerting control by the UPFC Device.

Experiments were also conducted to study the spare stored energy in the capacitor of the UPFC Inverter (when generation is higher and utilization is lesser at the load end). This spare power was diverted through a DC transmission line connected at the junction of the charged capacitor. The spare power was transferred to another load located distantly where at the other end of the DC transmission line an inverter was placed to convert it back to the AC supply for the local load. The capacitance was also varied in steps from 5,000 to 80,000 MFD. This resulted into reservoir for excess energy. This saved power which otherwise would have been wasted had it not been stored in the capacitor. *This experiment showed an economic utilization of power.*

Observations were made about power system network studies on the Power System Monitor as a real time simulation of the problem under study; the advantage was fundamental laws of electricity and physics were automatically followed.

The model of the Power System Monitor can be used for making observations for:

- *Optimum utilization* of existing transmission system
- Power system *reliability* and availability
- Dynamic and transient grid *stability control*
- *Increased utility* of power and energy
- System *reliability* in terms of – *interconnections, control, fault rectification,* Protection, Power Factor correction and overall performance work.

The use of SCADA introduced efficiency due to automatic control to a pre-determined *optimization* limits set for its operation thereby, contributing to the economic factors related to the operation, control and transmission of power. Option was provided for detaching the SCADA device from the model for manual operation.

[4] Ramleela Khare, Filipe Rodrigues E Melo present in their paper "Management of High Voltage DC Power" presents new techniques of management of HVDC (High Voltage Direct Current) power transmission. Several aspects of comparison between AC and DC power transmission have been studied *highlighting what would result in economical, efficient and maximum utilization of the power in existing system of transmission.* AC transmission is economical up to certain length of transmission. The data shows that beyond 500 Km length HVDC transmission is more profitable.

Operational factors of AC and DC have been also compared and on the basis of studies strong recommendation has been made for changing over from existing AC long distance transmission to DC system. The same AC tower line can be utilized for higher voltage transmission of DC with minor modifications. The cost of DC conversion is offset by using only single conductor and tower height (right of way usage for DC) as compared to AC. For a very long length of transmission line, applications of DC transmission have been made up to 800 KV and 5000 MVA. It is conceived that in the future the majority high voltage grid network will be that of HVDC lines.

HVDC technology has scope of future research in integrating Generating Stations and management strategies have to be designed for reliable system operation and transmission of power. *The future progress of research is dependent on development in* *power electronics to support economic management of electrical power grid and other power utilities.*

[5] Ramleela Khare, Filipe Rodrigues E Melo outline research conducted on "Technological Innovation and its Management". The research highlights that with the right kind of innovation a new industry can be set up. Innovations in many cases enhance the national resources by import substitute, thereby save foreign exchange, generate employment and provide secured future. The efforts involved in any innovation are enormous, therefore evaluating the objective and scope of an innovative idea becomes important.

Conception of an Innovation and its implementation is a miracle boost to an industry. A single innovation is capable of establishing a new industry in the shortest time, say a year. The case history discussed in the paper confirms that if the innovation is managed well it can cause phenomenal growth of an organization. Of course, there are several difficulties in creating an innovation. There are tough problems to be solved but it is worth it in the end. The innovation, development and launch of the product Master Cable Fault Locator of the case history needed to overcome technical and commercial difficulties.

In this case, the power transmission cables comprised low insulation fault with or without the foreign potential, short faults, earth faults, and break faults of different lengths and cross sections of the faulty cable. A new technique had to be worked out.

The technique of *potential distribution* was perfected for locating the low insulation faults. *For break faults method of capacitance charge and discharge was developed.*

Not only innovation requires inter-disciplinary technological efforts but also management of commercial aspects apart from financial investments and study of risk factors as all innovations do not succeed technologically or commercially.

The management of a technological innovation for quick & high growth needs team work of technical people trained in different areas to suit the innovation. Here, a management that understands the personnel, trusts them and helps in ways to meet their emotional, financial needs like promotion, motivation, job satisfaction, incentives and above all a friendly environment contribute in achieving the targets.

[6] Ramleela Khare, Filipe Rodrigues E Melo in their paper on "Reliability and Maintenance Management of Power System Networks" describe the equipment for overall maintenance of the cable network of the HVAC and HVDC transmission of power through the underground cable network. For several reasons the underground cables develop faults and reliable equipments are required for quick localization faults.

This paper highlights Cable Fault Locator that can locate low insulation, short and earth faults caused by deterioration of the insulation or external damage. No suitable handy and cost effective Cable Fault Locator exists that can handle this kind of partial faults particularly when such faults are susceptible to acquiring induced potential from the high voltage sources of overhead lines in the vicinity. The Cable Fault Locator works on the Potential

Distribution principle and it is provided with software to take the data to memory and calculate percentage distance to fault.

Percentage distance to fault =

$$\frac{2\,(ebi \pm Fp)}{(ebi \pm Fp) + (eb2 \pm Fp)} \text{ -------- } (1)$$

Where, eb1 = potential as shown in the figure from the test point to fault point of the loop, eb2 = balance potential from the other end of the loop up to the point of fault.
Fp = potential between the two faulty cores, Anand Khare (1985). This data is taken to the memory and calculations are made as per the formula provided in the memory. Instrument automatically does the calculation from the data on pressing COMPUTE Button and the results are displayed on the intelligent DPM (Digital Panel Meter). The automatic feature enables the instrument to adjust the magnitude of current depending on the cross section and length of faulty cable.

The instrument is versatile to locate *all types of faults* that occur in power cables. The requirement of a perfect good core to form circuit is not crucial because a comparatively better core can serve this purpose. This instrument has superior features to pulse reflection type of cable fault locators because the Pulse Reflection instrument has limitation in locating low insulation faults, faults with induced potential and earth faults. Other severe disadvantages of Pulse Reflection are it must have in the cable under test RLC parameters in sufficient measure for the reflection of the pulse. For cables of different gauges the technique becomes inadequate.

The Master Cable Fault Locator innovated here is free from these limitations and it can handle any cross section and length of the cable by automatically adjusting the signals.

The Cable Route Tracer described here has Audio Visual signal output. This route tracer has new features compared to existing technology which is based on technique of metal detection which gives a bleep signal which is misleading when large networks of cable are present. The design of the cable route tracer described in this paper is of the audio signal of musical range which can be easily identified and sensed when fed to the core of the cable which is earthed at the far end. See the connection circuit is shown in the figure.

The signal generates electromagnetic and electrostatic fields in the core under test. As the core is earthed the signal is easily detected above the ground by the Sensor which detects electrostatic and electro-magnetic fields through the transducer of the sensing device. By walking with the sensor pointed to ground, the sensor will pickup music signal. The sensor is provided with a built in amplifier and speaker to announce the route of the cable through a musical tone. The Route Tracer also identifies a particular cable from a bunch of cables in the pit.

The significance of the work stated in this paper is that the product designed fulfills the need for a low cost, portable and accurate equipment that can be used for majority of high voltage underground cables in private and public establishments for locating cable faults arising due to low insulation, short and earth and present a generalized solution for locating all types of faults in HV power cables of different cross section and length; it is a user friendly Intelligent Automatic Cable Fault Locator Set preprogrammed to provide the results with a touch of the button. The Master Cable Fault Locator has reached perfection. This equipment alone can take care of all types of faults in all types of cables as discussed in the earlier sections.

[7] Ramleela Khare, Filipe Rodrigues E Melo in their paper present "Dynamic Model for Protection of 400 kV Transmission Line Designed as a Benchmark for Power laboratory has been provided with:
1. Digital Numerical Distance (DND) Relay.
2. UPFC Devices Unified Power Flow Controller 3. Supervisory Control and Data Acquisition Architecture"
This relay protects the system by tripping the circuit in case of faults and gives distance to fault for all types of faults (Line to Ground, Double Line to Ground, Three Phase fault and Three Phase to Ground faults) in overhead transmission lines enabling fast restoration by clearing the faults. Application of *Digital Numerical Distance Relay* (DNDR) to the overhead lines solves all problems related to the rectification and monitoring of faults and safety of overhead high tension lines where reaching the fault for rectification would otherwise be very time consuming.

A dynamic model of an overhead line Fault Simulator of three phase real system with SCADA architecture was built to demonstrate overhead line maintenance using Digital Numerical Distance Relay. Experiments were conducted to study the working of the relay for its efficacy and procedures of usage by simulating different faults on the transmission line. This dynamic model comprised three phase generator, trans-mission lines (to simulate 400 kV Trans Line of 400 km) and Resistive and inductive loads with all the features of the real system that is the circuit breakers, reverse power relay, over current relay. This relay has become vital for the modern transmission systems. Many of the existing high voltage transmission lines which do not have this kind of relays are now being modernized by adding on these.

The dynamic model designed and constructed by the author provides complete information and know-how about usage of the relay for modernizing the existing systems and contributes to efficient and reliable management of overhead line maintenance.

CONCLUSIONS

An overall conclusion on the topic of research on Economic and Efficient Transmission and Control of Electrical Power in the Real system – Design of a SCADA Power System Monitor" sums up this diversified research to include all aspects of economic and efficiency related problems of transmission and control of power. This is studied by building dynamic models, conducting experiments on the models and interpreting the results for the data of the real system to establish the accuracy and versatility of the model and technique. The model has the feature of the real system including FACTS devices & SCADA. The research also includes HVDC transmission of power; management of technological innovations; efficient maintenance management of HVAC underground cable network and overhead line used for transmission of power.

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