IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 4, Issue3, June - July, 2016
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

Construction Of 3-Phase Grid Prototype

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Abstract

This paper describes construction of a 3-Phase Grid Prototype to simulate disturbances caused due to sudden shut down of generator, load or fault. It has capacity to simulate three generators, three loads and three transmission lines. It is provided with SCADA automation for remote operation and FACTS Device.

Keywords: 3-Phase Grid Prototype, Power System Simulator, SCADA, UPFC.

Introduction

This research paper presents construction of a dynamic model simulating 400 kV transmission system to study the Dynamic stability during power flow in an interconnected grid system. The model is built to study disturbances caused during heavy loadings and fault conditions and stability achieved by using external devices. It has Supervisory Control and Data Acquisition to automate and monitor all the nodes. The SCADA system also has the feature to maintain the generators in a synchronous state in the grid.

[1] Ramleela Khare et.al (2012), in their paper "Economic and Efficient Management of Transmission and Control of Electrical Power - Design of A SCADA Power System Monitor" have constructed a "Power System Monitor" to simulate and study power system network on scaled down parameters. It is provided with simulated generators, transmission lines and loads. This model has SCADA architecture and UPFC device. In their paper the author presents the economics and efficiency achieved by SCADA and UPFC.

Their paper discusses about the experiments which were carried out:

(1) Power Flow (2) Fault Analysis (3) Shunt Admittance Y/2 (4) Shunt Compensation through Inductors (5) Parallel Transmission Lines (6) UPFC (Unified Power Flow Control)
(7) Control of Reactive Power in Trans Lines

They concluded that how UPFC device enhances utilization of transmission lines resulting into financial benefit and purpose of making the model was to analyze first hand study of aspects related to economic management of power transmission.

[2] Ramleela Khare et.al (2014), in their paper "Dynamic Model of 400 KV Line with Distance Relay" have built a dynamic 3-Phase model simulating 400kV, with 450 km transmission line length representing Lucknow – Sultanpur transmission system. This model has SCADA features and Digital Numerical Distance Relay (DNDR). Experiments using DNDR were performed by simulating different types of faults. This model has three, 3-Phase generators / four Transmission lines / two Passive loads and protection devices.

On this model studies were made on:
1. Fault Clearing in the Three Zones of the Transmission Line. 2. Obtaining Distance to Fault. 3. Power Flow in Grid Network. 4. Control of Power in Transmission Lines using UPFC device. 5. Application of SCADA.

[3] Ramleela Khare et.al, (2014), in their paper "Ac Network Analyzer a Dynamic Benchmark for Power System Study" has built a model "AC Network Analyzer" to study problems of power system in an interconnected grid network. The model has four generators, four loads and four transmission lines. Experiments were performed on this model on power flow with FACTS Devices.

The Multi Function Meter indicates Voltage, current, Volt Amp, Watts, Vars and Power Factor. The Analyzer was used to study generation and transmission of power flow / fault studies**:** symmetrical & unsymmetrical faults.
[4] Amit Shrivastava and Anand Khare, (2013) in their paper "Design of a SCADA Power System Monitor & its Application in Power Industry" have designed a model for practical study of power system networks working on scaled down parameters to represent generator, transmission lines and distribution of power to simulate the real time generation and transmission of power.

This monitor has SCADA architecture with wireless arrangement. They have outlined the efficient and economic management of power generation and transmission during peak loads through automation. The Power System Monitor demonstrates the application of SCADA architecture for automation.

3-Phase Grid Prototype
The authors of this paper ("Construction of 3-Phase Grid Prototype") have developed a model to study the dynamic stability in a power grid system. This model has SCADA archi-tecture

and FACTS Device to counter the distur-bances and achieve stability.

1. The Model

This simulator model has the capability to form a interconnected grid network to study power flow / fault studies and conditions arising in a given situation. The grid has provision to couple renewable energy source.

2. Structure

The model is 7.5 feet in length, 6 feet in height and 3 feet in depth. Inner shelves are of acrylic material on which all the electrical and electronic components are mounted and front and back covered by ACP sheets.

3. Layout

The Model constructed has three panels: Panel 1 comprises Controls of Generator no.1, 2 & 3 and on the desk transmission lines 1 and 2. Panel 2 has bus bars where the ends of Generator 1, 2 & 3 Load 1, 2 & 3 and transmission line 1, 2 & 3 are terminated. They can be interconnected through patch cords to form the desired circuit. Panel 3 comprises control of Load no. 1, 2 & 3 and on the desk Transmission lines 3. The inductors, resistors and other components are mounted inside the panel.

4. Capacity

This model has three generators, three loads and three transmission lines.

a. Generators (G)

The generator panel has two 3-Phase generators of 2 kVA capacity each and one 2kVA Solar Renewable energy source 415 Volts, three phase motor-generator sets are provided with motor drives, reverse power relay, short circuit relay with circuit breakers for their protection. Three phase digital Multi Function Meters (MFM) displays voltage, current, power factor, frequency, active and reactive power.

The multifunction meters also have RS285 port for data communication with computer software. The generator alternator output is stepped down by transformer to100 volts

The Motor-Alternator Control Panel

The two 3 Phase / 2 kVA motor alternator sets (Generator supply 1 and 2) have a separate Control Panel with digital meters and variac arrangement to control speed and excitation of motor-generator and another variac for varying the voltage.

Solar Renewable Energy Source: 3-Phase 2kVA with sinusoidal output.

b. Loads (L)

The passive load comprises of Resistive / Inductive / Capacitive banks and protection devices.

c. Transmission Lines (TL)

The TL has pi section divided in three sections of 200 km each giving a total length of 600 km (see table no 1). TL also has the necessary protection devices - MCB / over current relay. The TL is provided with the digital MFM with RS285 Port. The TL configuration is in the form of a pi-section with RLC values. One MFM is provided at the Sending end of the TL and another at the Receiving end of each section.

Table no. 1

TL Parameters	**200 km**	**200 km**	**200 km**
Resistance	6 ohms	6 ohms	6 ohms
Inductance	200 mH	200 mH	200 mH
XL	66 Ohms	66 ohms	66 ohms
Capacitance	2.2 micro Farads (for pi 1.2 + 1.2)	2.2 micro Farads (for pi 1.2 + 1.2)	2.2 micro Farads (for pi 1.2 + 1.2)

5. Interconnection on the Model

(a) The panel 2 has arrangement for Inter-connecting generators, loads and transmission lines. (b) This panel has Banana Sockets in (R- Red, Y- Yellow and B- Blue) colors where the two ends of generator, transmission line and loads terminate. These can be interconnected to form the grid network. (c) The Green Sockets are the earth points. (d) The RYB switches on the panel of Generator, Transmission Line and Load of Area I, Area II and Area III control the output on the Central Panel.

6. Components on the model

Table no. 2

List of Items	Gen Panel I / II / III	Load Panel I /II / III	Trans Line Panel I / II / III	Alternator Control Panel	Desk of Central Panel
Dimmer stat				3	
MPCB	3				
Multi Function Meter	3	3	3		3
Over Current Relay	3	3	3		3
Miniature Circuit Breaker	3	3	9		
R, Y, B Switches	9	9	9		3
Rotary Switch	3	9			
Resistors		3	3		
Inductors		3	3		
Capacitors		3			
UPFC					1
DC Motor, 5HP 220V/ 1500 rpm				2	
AC Alternator 3-Phase / 2kVA, 215V				2	
Solar Renewable Energy Source				1	

7. Block Diagram of Connections

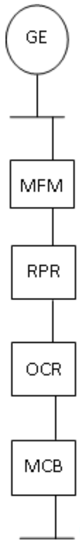

Fig. 1: Generator

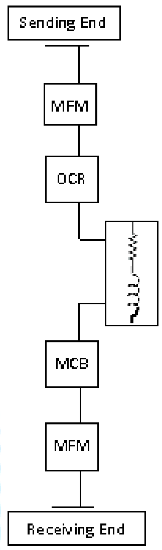

Fig. 2: Transmission Line

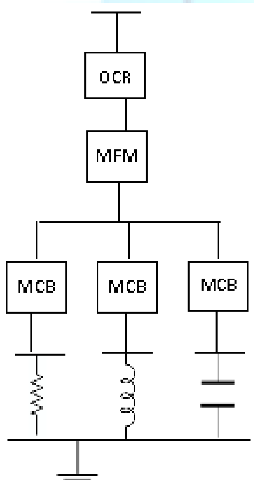

Fig 3: Load

GEN – Generators

RPR – Reverse Power Relay

OCR – Over Current Relay

MFM – Multi-Function Meter

MCB – Miniature Circuit Breaker

8. Co-relation of Base Values between Real System and 3-Phase Grid Prototype

a. The Real System

Base power: 40 MVA

Base Voltage: 400 kV

I = 40MVA/ 400 kV =

Base Current: 100 Amps ---------- (1)

Z = 400kV/100 A =

Base Impedance: 4000 ohms

The Base Impedance of 2000 Ohms of Real System and the same value on the model co-relates conversion made to real system as indicated in equation (2)

b. 3-Phase Grid Prototype

400 Volts of the 3 phase generator output is stepped down to 100 volts / phase for the 3 phase through a three phase transformer

Base Voltage: 100 Volts per phase ------- (2)

V/Z = 100/4000 = Base Current: 25 mA

25 mA represents 40MVA Power in real system and 100 Volts represents 400kV of real system see equation (1)

Base Impedance: 4000 ohms

Frequency: 50 Hz

9. SCADA - Supervisory Control and Data Acquisition

SCADA has been provided on this model to monitor the different nodes and control components of the hardware model. The values (V / I / VA / Pf / Watts / Vars) displayed on all

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the Multifunction meters and status points at nodes on the model are retrieved on the computer through wireless system and then the components (contractors / motorized dimmer stat / motorized rotary switches) on the model are controlled from the computer (see fig. 4).

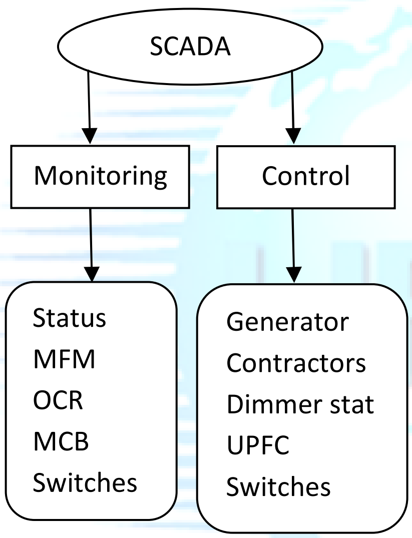

Fig 4: SCADA Function chart

a. Hardware

- Programmable Logic Controller (PLC) controls the relays when the command from the computer is received and PLC also acquires data from the communication ports of the model and transmits to the computer.
- Five sets of Relays (each relay set has eight relay points) are connected to the PLC and controlled by the computer. These relays are for control as well as to check the status of signal reaching at different nodes.
- 24 Volts DC supply (SMPS -Switched Mode Power Supply) supplies power to PLC for its function.
- Computer with the programmed Software is the main controlling and data acquiring station where the user operates the required functions.

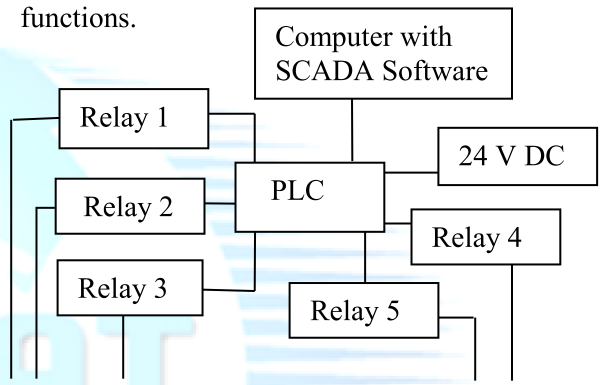

Image 1: SCADA hardware components connected to the model with provision for 3 generators, 3 loads and 3 transmission lines

The computer is connected to the PLC to acquire the data on the computer and all the control settings and options for the operation of the model are sent to the PLC from the computer. The PLC operates on 22 Volts DC supply and controls all the relay sets connected to the 3-Phase Grid Prototype.

The relays can perform:

a. ON / OFF functions
b. Selection function
c. Monitor the status of signal

The Multi-Function Meters are provided with RS285 ports. Positive and negative points are connected in series and then finally connected to the PLC. The PLC is then set to recognize and identify each meter's IP address and then acquire the data in sequence. This information is transferred to the computer software (see fig. 2).

b. Software Comprises: Front End Design:

The front end design of the software displayed on the desktop computer screen is a replica of the 3-Phase grid prototype. On this model SCADA controls the ON / OFF function of generator, load and transmission lines for coupling and decoupling. The status of every node is monitored for the power reaching at circuit breakers, over current relays, rotary switches and central panel. The panel contains three generators, three loads and three transmission lines. There are contactors and RYB illuminated push buttons which are selectable and control the coupling and decoupling of the circuit. The ELR, OCR, MCB nodes status points are monitored for whether the voltage supply has reached the bus bars or not. The central portion of the image gets lighted up with red, yellow and blue color indicating that the voltage has reached the bus bars.

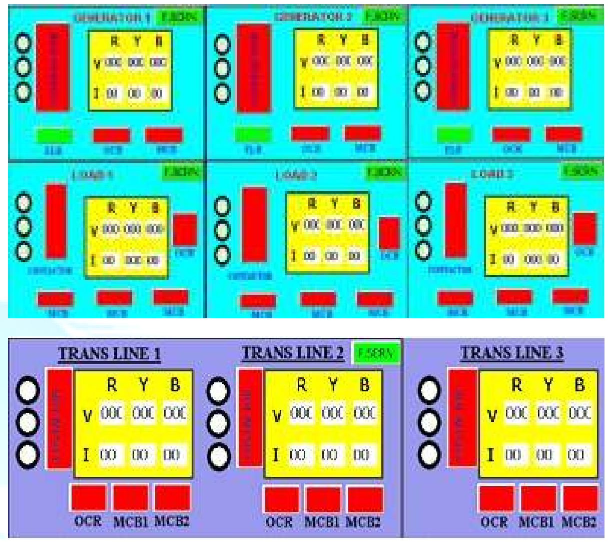

Image 2: Front End design of the software

Conclusions

The 3-Phase Grid Prototype constructed is capable to study the state of the interconnected grid during disturbances and bringing about dynamic stability in the grid network. The model simulates a grid capacity of three generators, three loads and three transmission lines. It has SCADA Architecture and FACTS Device to stabilize the grid as an external device. To verify the design, experiments on power flow and fault analysis were performed (see figure no 6). The experimental work on stability studies is in progress. Scope of SCADA functions involve:

1. Monitoring Speed and Frequency
2. Supervising the status of circuit breakers, protective relays
3. Generation operations planning
4. Active and reactive power control

5. Alternator protection
6. Load scheduling
7. Limiting peak power demand

Simulated Study

This model is a suitable benchmark to simulate the real system. It simulates 400 kV, 600 km transmission line and works on scaled down parameters with calculated Base Values to co-relate with real system.

Interconnected grid system is shown in (fig. 6).

G – Generator

L – Load

TL – Transmission Line

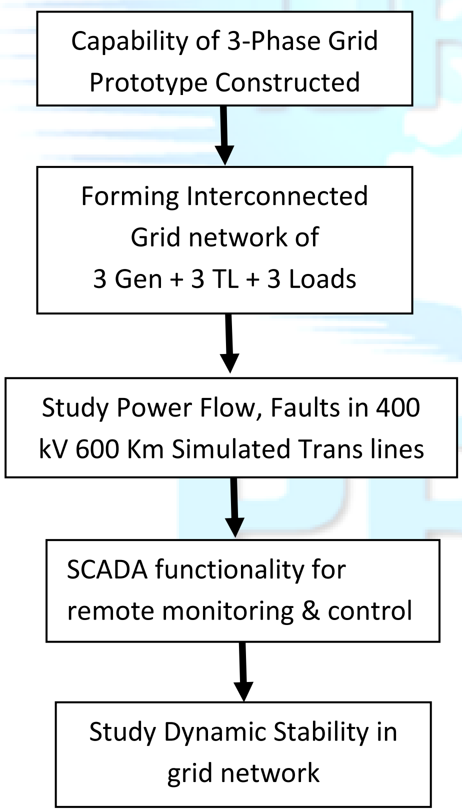

Fig 5: Algorithm of 3-Phase Grid Prototype

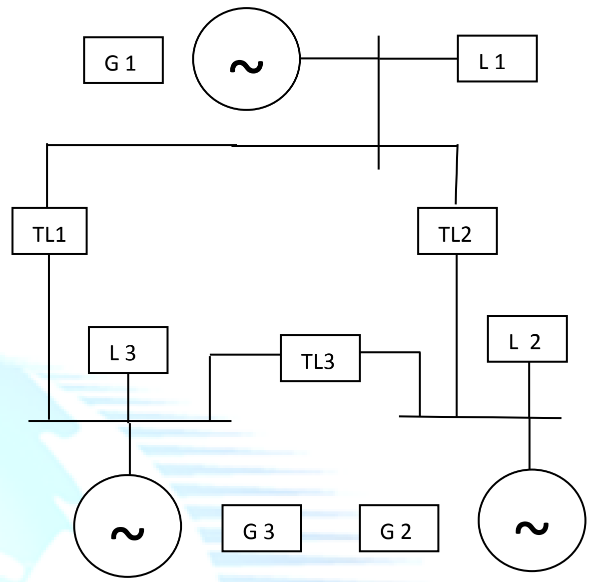

Fig 6: Grid comprising 3 Generators, 3 Transmission Lines & 3 Loads.

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ACKNOWLEDGEMENT

Thanks to Dr Ramleela Khare, Director Research, The ISRC Company, Hyderabad, for his suggestions in constructing the model.

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