An-Najah National University.

Faculty of Engineering

Electrical Engineering Department

Electric Power Systems Lab

63527

Student manual

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Groups and experiments distribution during the first or the second semester

groups / weeks	Group 1	Group 2	Group 3	Group 4
Week 1	Exp. 1	Exp. 1	Exp. 1	Exp. 1
Week 2	Exp .2	Exp 2	Exp. 3	Exp. 3
Week 3	Exp. 3	Exp. 3	Exp. 2	Exp. 2
Week 4	Exp. 4	Exp. 4	Exp. 5	Exp. 5
Week 5	Exp. 5	Exp .5	Exp. 4	Exp. 4
Week 6	Exp. 6	Exp. 6	Exp.7	Exp. 7
Week 7	Exp. 7	Exp. 7	Exp. 6	Exp. 6
Week 8	Exp. 8	Exp. 8	Exp. 9	Exp. 9
Week 9	Exp. 9	Exp. 9	Exp. 8	Exp. 8
Week 10	Exp. 10	Exp. 10	Exp. 11	Exp. 11
Week 11	Exp. 11	Exp. 11	Exp. 10	Exp. 10
Week 12	Exp. 12	Exp. 12	Exp. 13	Exp. 13
Week 13	Exp. 13	Exp. 13	Exp. 12	Exp. 12
Week 14	Review and discussion			
Week 15	Practical and theoretical exams			

List of Lab experiments:

Experiment #1

Introduction to power systems lab

Objectives

1. **To discuss the instructions of public safety rules and to show the importance of these rules in the electric power systems lab.**
2. **To clarify the information and practical experience gained by the students through this lab and its importance in life.**
3. **Distribution of students into working groups to stimulate teamwork**
4. **To discuss the course outline and to identify the laboratory experiments.**
5. **To describe all of the power systems equipment and devices and how to use and deal with these apparatus safely.**
6. **To guide the students how to prepare the experiments before doing them in the lab and how to write the report of the experiments.**

Experiment #2

Motor-Generator Unit

Objectives:

1. To be familiarized with the procedures required to start and stop syn. Generators.
2. To understand the voltage characteristic of the Syn. Generator loaded with various resistive, capacitive and inductive loads.
3. To understand the regulation characteristic required to compensate the voltage of the Syn. Generator loaded with various resistive, capacitive and inductive loads.

Introduction

What is The Generator?

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy. A generator forces electric charge (usually carried by electrons) to flow through an external electrical circuit. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air, or any other source of mechanical energy.

The reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity, and frequently make acceptable generators.

Equivalent circuit.

The following circuit diagrams illustrate the per phase equivalent circuits of a round rotor synchronous machine in the generator mode.

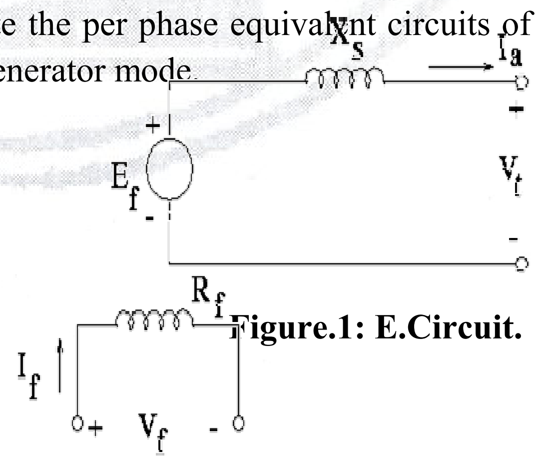


Figure.1: E.Circuit.

Vf: Is the field voltage of the exciter.
Ef: Is the Generator internal voltage.
Vt: Is the Generator Terminal voltage.
Xs: Is the Generator Reactance.
Rf: Is the field resistor.
If: Is the field current.
Ia: is the output current.

Phasor Diagram of standalone synchronous generator

An understanding of how load changes effect the operation of the generator can be obtained by considering the simplified phasor diagram.

E: Is the Generator internal voltage.
V: Is the Generator Terminal voltage.
Xs: Is the Generator Reactance.
IA: is the output current.
θ: is the Power factor angle.
δ: is the torque angle.

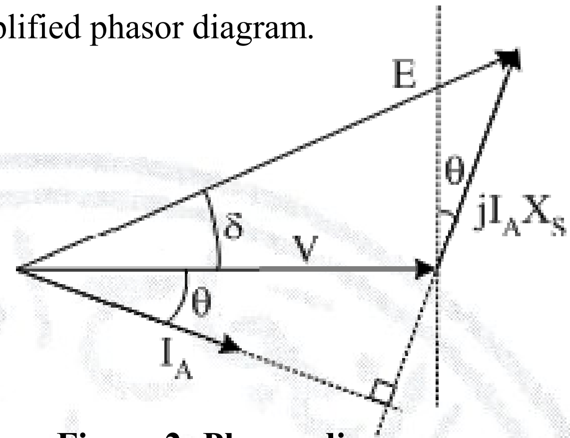


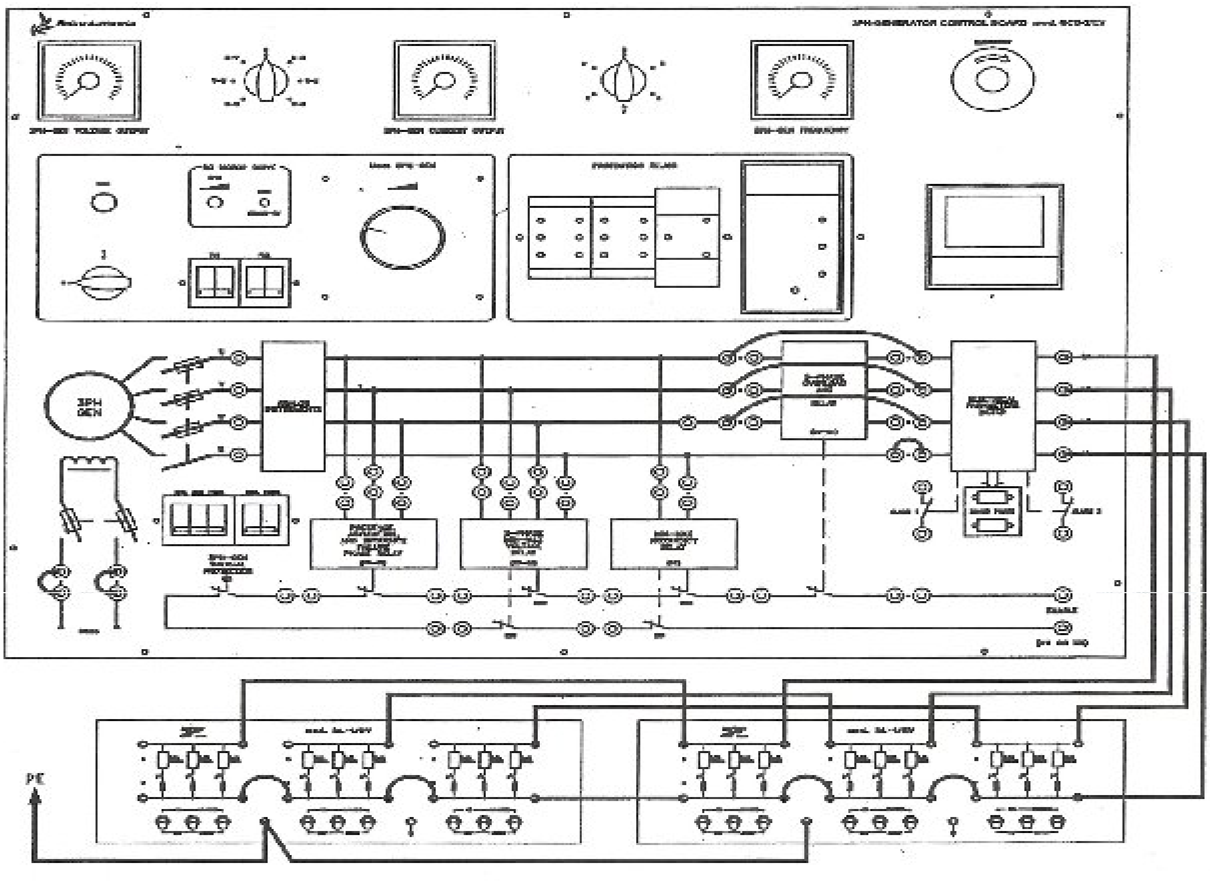
Figure.2: Phasor diagram

Equipments required (Apparatuses):

1. Control board for the generating set mod.GCB-2/EV.
2. Synchronous generator-motor unit mod.MSG-1/EV.
3. Variable resistive load mod.RL-2/EV.
4. Variable inductive load mod.IL-2/EV.
5. Variable capacitive load mod.CL-2/EV.

Experimental procedure:

1. Make sure that the generating unit set is well connected, and then continue to complete wiring the control board and make sure that protection relays are not connected.
2. Connect a parallel combination of resistive, inductive and capacitive loads.
3. Make sure that the digital power analyzer is well connected.
4. Connect a digital ammeter to the excitation circuit of the synchronous Generator, so you end up with the connections shown in figure#1



Figure#1

Part I: Load characteristic at constant excitation

1. Make sure that all loads are switched off .
2. Activate the prime mover and adjust the frequency to 50Hz with help of the power analyzer.
3. Adjust the excitation current of the syn. generator to obtain 400V .
4. Set the syn. generator under load by inserting the first step of the resistive load (R_L=720Ω) and write down the load current (**I_{Load}**), terminal voltage(**V_T**) and the power consumed by the load then calculate the voltage regulation (**VR).**
5. Repeat the previous step but with different values of the resistive load and fill table(1).
6.

$R_{Load}(\Omega)$		I_{Load} (A)	V_T (V)	P (W)	V.R(%)
Open circuit		0	400	0	
A	720				
B	360				
A//B	240				
C	180				
A//C	144				
B//C	120				
A//B//C	103				

Table(1)

7. Switch off all loads and make sure that the no-load voltage is 400V.
8. Use a fixed 720Ω resistance in parallel with first step of the **inductive** load and write down the load current (I_{Load}), terminal voltage(V_T) and the power consumed by the load then calculate the voltage regulation (**VR).**
9. Repeat the previous step but with different values of the **inductive** load and fill table(2).

LOAD		I_{Load} (A)	V_T (V)	P (W)	V.R(%)
R(Ω)	L(mH)				
Open circuit		0	400	0	
720Ω	A				
720Ω	B				
720Ω	A//B				
720Ω	C				
720Ω	A//C				
720Ω	B//C				
720Ω	A//B//C				

Table(2)

10. Switch off all loads and set the no-load voltage at 300V.(why?)
11. Use a fixed 720Ω resistance in parallel with the first step of the **capacitive** load and write down the load current(**I_{Load}**),terminal voltage(V_T) and the power ,then calculate the voltage regulation (**VR).**
12. Repeat the previous step but with different values of **capacitive** load and fill table(3).

(***CAUTION: DO NOT allow the terminal voltage to cross 450V***)

LOAD		I_{Load} (A)	V_T (V)	P (W)	V.R(%)
R(Ω)	C (μF)				
Open circuit		0	300	0	
720Ω	A				
720Ω	B				
720Ω	AB				

Table(3)

Sketch the terminal characteristic of this generator for different type of loads (R, RL & RC) . $V_T = f(I_L)$

Part II: Regulation characteristic at constant terminal voltage

1. Make sure that all loads are switched off.
2. Set the terminal no-load voltage to 400V by varying the excitation current.
3. Set the syn. generator under load by inserting the first step of the resistive load (R_L=720Ω) .
4. Increase the excitation current to obtain 400V line to line voltage the on generator terminals and write down the values of load current, excitation current and the power.
5. Repeat the previous step but with different values of resistive loads and fill table(4). For each steps of varying load you must return the value of terminal voltage to 400 V

(CAUTION: DO NOT allow excitation current to cross over 0.43A)

R_{Load}(Ω)		I_{Load} (A)	$I_{exitation}$ (A)	P (W)
Open circuit		0		0
A	720			
B	360			
A//B	240			
C	180			

Table(4)

6. Decrease the excitation current, switch all loads off then set the no-load voltage to 400V.
7. Set the syn. generator under load using a fixed 720Ω resistance in parallel with first step of the **inductive** load .
8. Increase the excitation current to obtain 400V and write down the values of the load current, excitation current and power.
9. Repeat the previous step but with different values of **inductive** load and fill table(5).

(CAUTION: DO NOT allow excitation current to cross over 0.43A)

load		I_{Load} (A)	$I_{exitation}$ (A)	P (W)
R_{Load}(Ω)	L(mH)			
Open circuit		0		0
720	A			
720	B			
720	A//B			
720	C			

Table(5)

10. Decrease the excitation current, switch off all loads then set the terminal no-load voltage to **300V.**
11. Set the syn. generator under load using a fixed 720Ω resistance in parallel with first step of the **capacitive** load .
12. **Decrease** the excitation current to obtain 300V and write down the values of the load current, excitation current and power. (Be Quick)
13. Repeat the previous step but with different values of **capacitive** load and fill table(6).

(CAUTION: DO NOT allow excitation current to cross over 0.43A)

load		I_{Load} (A)	$I_{exitation}$ (A)	P (W)
R_{Load}(Ω)	C (µF)			
Open circuit		0		0
720	A			
720	B			
720	A//B			

Table(6)

Sketch the regulation characteristic of this generator for different type of loads (R, RL & RC) . $I_f = f(I_L)$

Question1

What are the effects of increasing loads on the terminal voltage in each case ?

Question2

How can we reduce those effects ?

Question3

How can we protect the consumers from those effects ?

Question4

Draw a phasor diagram to explain the effect of resistive load upon the terminal voltage of the synchronous generator

Question5

Draw a phasor diagram to explain the effect of resistive inductive load upon the terminal voltage of the synchronous generator

Question6

Draw a phasor diagram to explain the effect of resistive capacitive load upon the terminal voltage of the synchronous generator

Write down your conclusions:

Experiment # 3

Transmission Line at NO Load

Objectives

To operate single and dual transmission lines at no load while changing the connection of transmission line equivalent capacitance and notice the changes on the receiving voltage, charging current, active power, reactive power and power factor.

Introduction:

In this experiment we will study the operation of power system transmission line in no load condition, and study the effect of this case at different value like, sending end voltage receiving end voltage, power factor, and the amount of reactive and active power at the sending end of the transmission line.

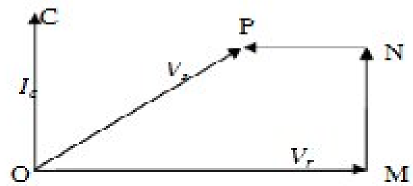
A long transmission line draws a substantial quantity of charging current. If such a line is open circuited or very lightly loaded at the receiving end, the voltage at receiving end may become greater than voltage at sending end. This is known as *Ferranti Effect* and is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. Therefore both capacitance and inductance is responsible to produce this phenomenon.

The capacitance (and charging current) is negligible in short line but significant in medium line and appreciable in long line. Therefore this phenomenon occurs in medium and long lines. .

The **Ferranti Effect** occurs when current drawn by the distributed capacitance of the transmission line itself is greater than the current associated with the load at the receiving end of the line. Therefore, the Ferranti effect tends to be a bigger problem on lightly loaded lines, and especially on underground cable circuits where the shunt capacitance is greater than with a corresponding overhead line. This effect is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. As this voltage drop affects the sending end voltage, the receiving end voltage becomes greater. The Ferranti Effect will be more pronounced the longer the line and the higher the voltage applied.

The Ferranti Effect is not a problem with lines that are loaded because line capacitive effect is constant independent of load, while inductance will vary with load. As inductive load is added, the VAR generated by the line capacitance is consumed by the load.

Represent line by equivalent π-model.



Line capacitance is assumed to be concentrated at the receiving end.

OM = receiving end voltage V_r
OC – Current drawn by capacitance – I_c
MN – Resistance drop
NP – Inductive reactance drop

Therefore;
OP = Sending end voltage at no load and is less than receiving end voltage (V_r)

Transmission line at no load:

*Vs = A*VR + B * IR*

IR= 0 (no load)

VR=Vs/A

At this case A <1 which give that VR>VS as shown in the phaser diagram above

Equipments required (Apparatuses):

1. Simulator of electric lines mod. SEL-1/EV.
2. Variable three-phase power supply mod. AMT-3/EV , in option three-phase line generated by the generator control board mod. GCB-1/EV , or a fixed three-phase line 3 x 380 V.
3. Three-phase transformer mod. P 14A/EV.
4. Set of leads/jumpers for electrical connections.
5. 2 electromagnetic voltmeters with range of 250 – 500 Vac.
6. 1 electromagnetic ammeter with range of 100 mAmp ac.
7. 1 electromagnetic wattmeter with low power factor 1-2 A / 240-480 V.
8. The instruments of the generator control boards mod. GCB-1/EV or two digital instruments for measuring the parameters of electric energy in three-phase systems mod. AZ-VIP, can be used as alternative.

Preparing the exercise

1. Start this exercise considering the transmission LINE 1 with the following constants: Resistance = 25 Ω; Capacitance = 0.2 μF; Inductance = 0.072 H; Length = 50 km; Section = 35 mm² - conductor of copper. As regards other parameters, refer to the table 2.1.
2. If necessary, remove all the jumpers of the LINE 2 not considered.
3. Turn the breakers at the origin and at the end of the LINE 1, to OFF.
4. Connect the measuring instruments between the left busway and the terminals at the beginning of the LINE 1 and the right busway.
5. Connect the jumpers with the set of left capacitors, only in the LINE 1, to reproduce the capacitance between active conductors (called CL). These capacitors can be connected either in star or delta configuration. The delta connection will ensure stronger capacitive currents.
6. Adjust the position of the selector Resistance LINE 1 at the value of 25 Ω.
7. Connect with the variable three-phase power supply by inserting the three-phase insulation transformer.
8. The transformer is used to insulate the line from the user mains to avoid that, when connected, the current unbalances of the capacitance CE (capacitance to the ground) can provoke the untimely intervention of the differential protections of high sensitiveness. If the power supply is insulated from the mains, that is it is not grounded, this three-phase transformer can be omitted.

Single Transmission Line

Connect the circuit as shown in figure #1

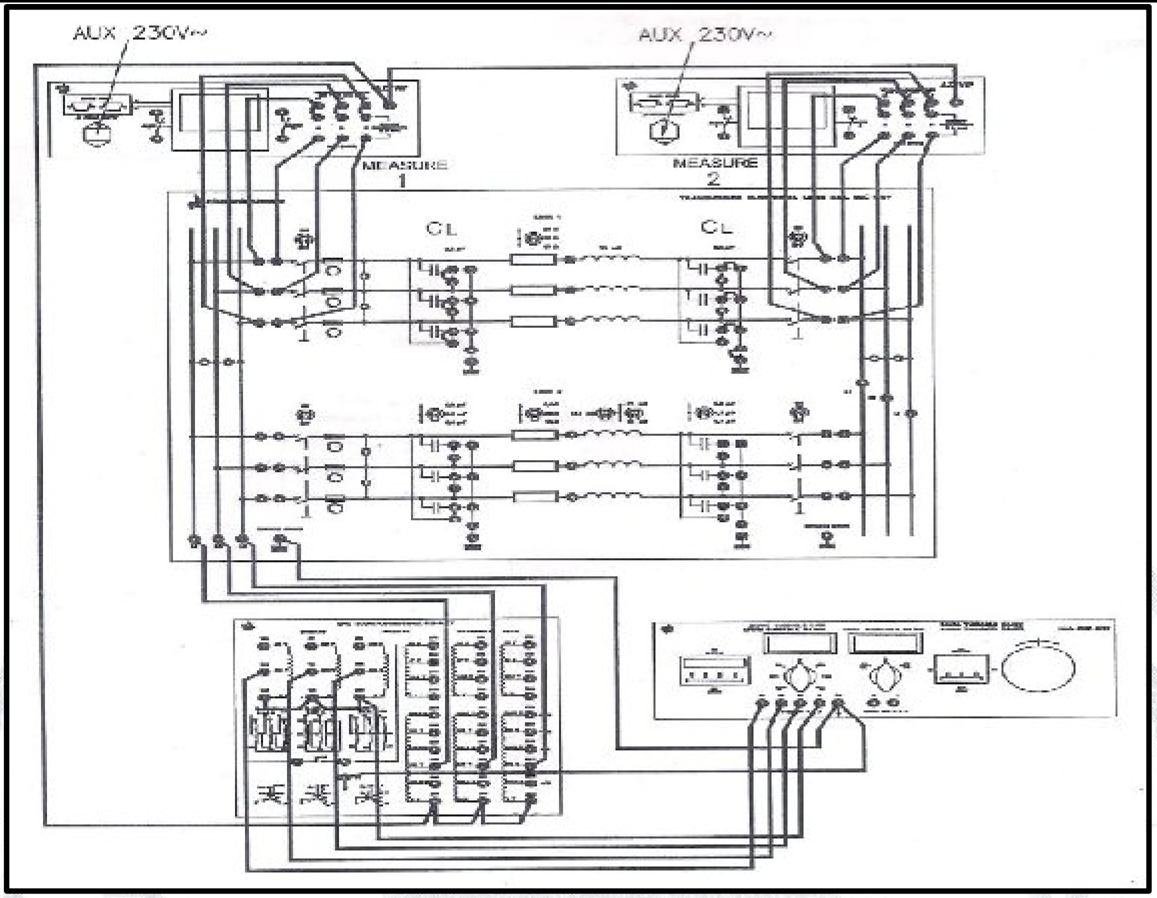


Figure #1

Connection #1

1. Connect the capacitors at the sending end of the transmission line on Δ connection
2. Connect the capacitors at the receiving end of the transmission line on Y connection
3. Keep the voltage Vs=380 v
4. Read the electric quantities on the measuring instruments and write them down in the following table (table #1).

(V)	(A)	(W)	(Var)		(V)

Table #1

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Connection #2

1. Connect the capacitors at the sending end of the transmission line on Δ connection
2. Disconnect the capacitors at the receiving end of the transmission line
3. Keep the voltage Vs=380 v .
4. Read the electric quantities on the measuring instruments and write them down in the following table (table #2).

(V)	(A)	(W)	(Var)		(V)

Table #2

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Connection #3

- Connect the capacitors at the sending end of the transmission line on Δ connection
- Connect the capacitors at the receiving end of the transmission line on Δ connection
- Keep the voltage Vs=380 v .
- Read the electric quantities on the measuring instruments and write them down in the following table (table #3).

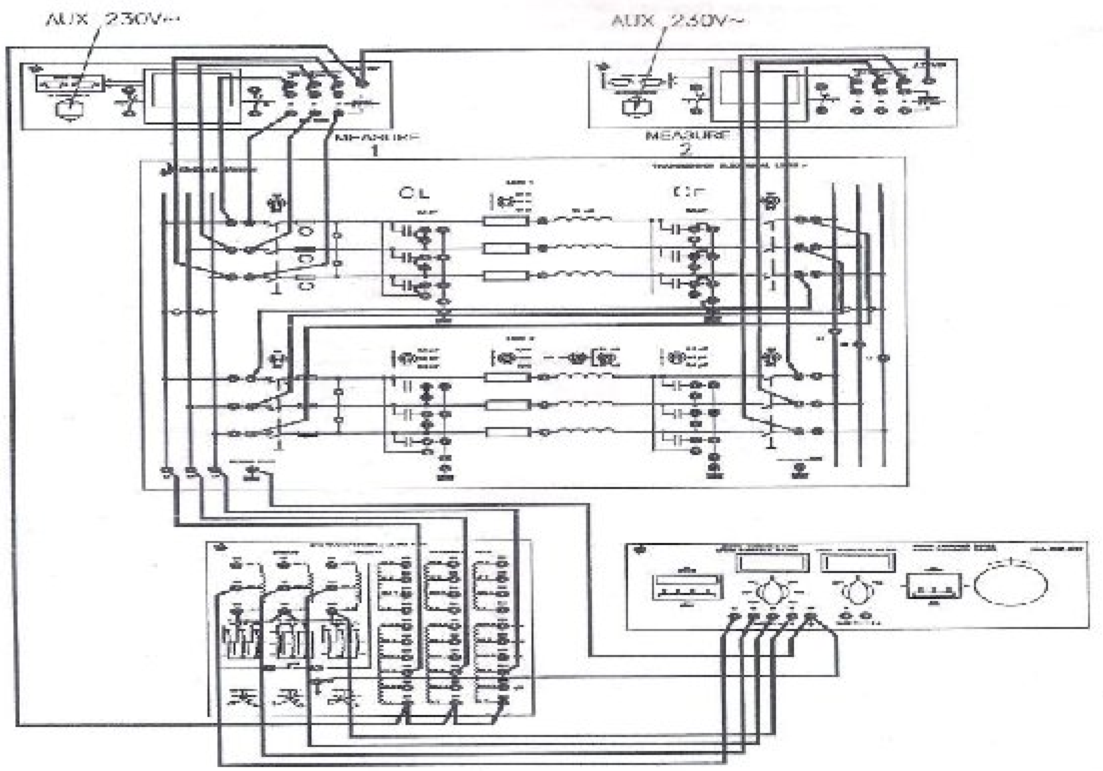
(V)	(A)	(W)	(Var)		(V)

Table #3

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Series Connection of Two Transmission Line at No load

Connect the circuit as shown in figure#2



Figure#2

Connection #1

1. Connect the capacitor at the sending end of the first transmission line to Δ connection
2. Connect the capacitor at the receiving end the first transmission line to Y connection
3. Connect the capacitor at the sending end of the second transmission line to Δ connection
4. Connect the capacitor at the receiving end the second transmission line to Δ connection
5. Keep the voltage Vs=380 v .
6. Read the electric quantities on the measuring instruments and write them down in the following table (table #4).

(V)	(A)	(W)	(Var)		(V)

Table #4

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Connection #2

1. Connect the capacitor at the sending end of the first transmission line to Δ connection
2. Connect the capacitor at the receiving end the first transmission line to Δ connection
3. Connect the capacitor at the sending end of the second transmission line to Δ connection
4. Connect the capacitor at the receiving end the second transmission line to Δ connection
5. Keep the voltage Vs=380 v .
6. Read the electric quantities on the measuring instruments and write them down in the following table (table #5). .

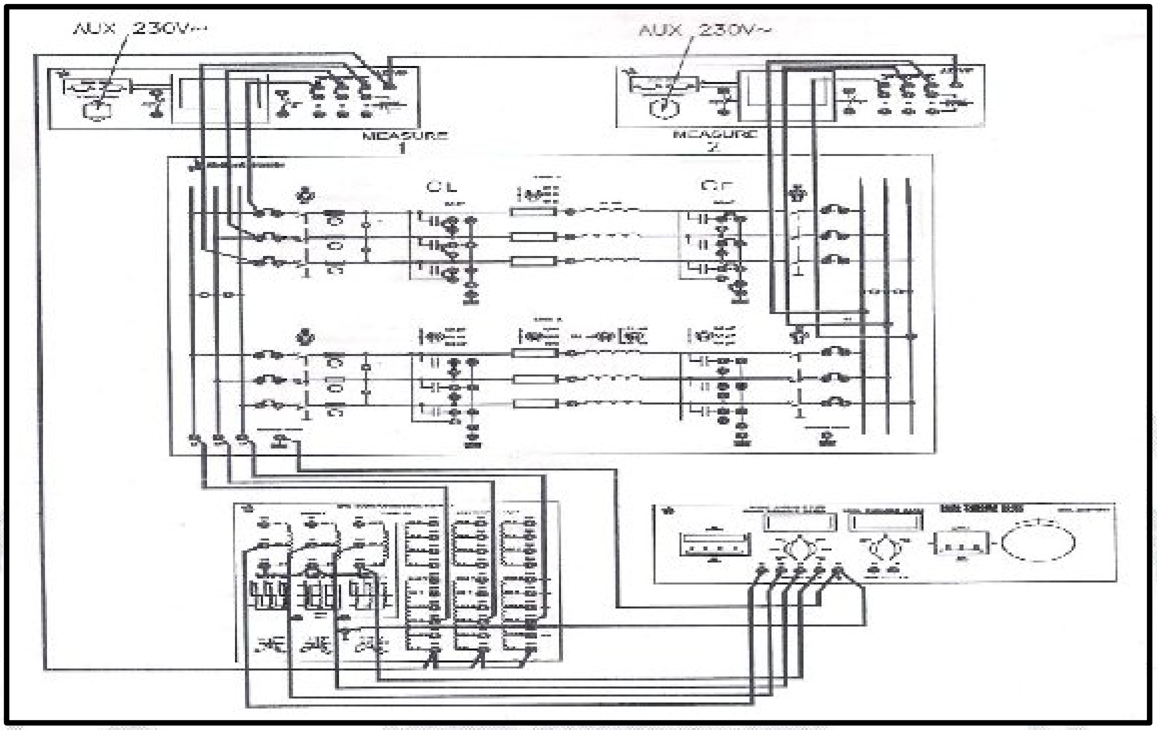
(V)	(A)	(W)	(Var)		(V)

Table #5

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Parallel Connection of Two Transmission Line at No load

Connect the circuit as shown in figure#3



Figure#3

Connection #1

7. Connect the capacitor at the sending end of the first transmission line to Δ connection
8. Connect the capacitor at the receiving end the first transmission line to Y connection
9. Connect the capacitor at the sending end of the second transmission line to Δ connection
10. Connect the capacitor at the receiving end the second transmission line to Δ connection
11. Keep the voltage Vs=380 v .
12. Read the electric quantities on the measuring instruments and write them down in the following table. (Table #6).

(V)	(A)	(W)	(Var)		(V)

Table #6

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Connection #2

13. Connect the capacitor at the sending end of the first transmission line to Δ connection
14. Connect the capacitor at the receiving end the first transmission line to Δ connection
15. Connect the capacitor at the sending end of the second transmission line to Δ connection
16. Connect the capacitor at the receiving end the second transmission line to Δ connection
17. Keep the voltage Vs=380 v .
18. Read the electric quantities on the measuring instruments and write them down in the following table (table #7).

(V)	(A)	(W)	(Var)		(V)

Table #7

Calculate the reactive power generated by the capacitors in this part and compare it with the measured value on the line

Question #1
Draw the phasor diagram for medium length transmission line operating at no load

Question #2
Stat e why the reactive power displayed in these experiments has negative singe?

Question #3
What are the problems you noticed when operating a medium or long transmission line at no load

Question #4
What action you can do to reduce the receiving end voltage at no load

Write down your conclusions

Experiment #4

Protection Relays

Objectives

Studying and applying a relay for:

1. Phase sequence, phase lacking and voltage asymmetry to a three phase circuit.
2. Max/Min three phase voltage.
3. Max/Min frequency of power production plant.
4. Overload in three phase line.

Introduction

A lot of problems can occur in any part of power system from generation until distribution like losing a phase, overload, over or under voltages than required, improper frequency and others.

In order to minimize the potential of such problems we protect the power system by protection relays, fuses and circuit breakers.

In this experiment we will study and handle different relays in matter of protection.

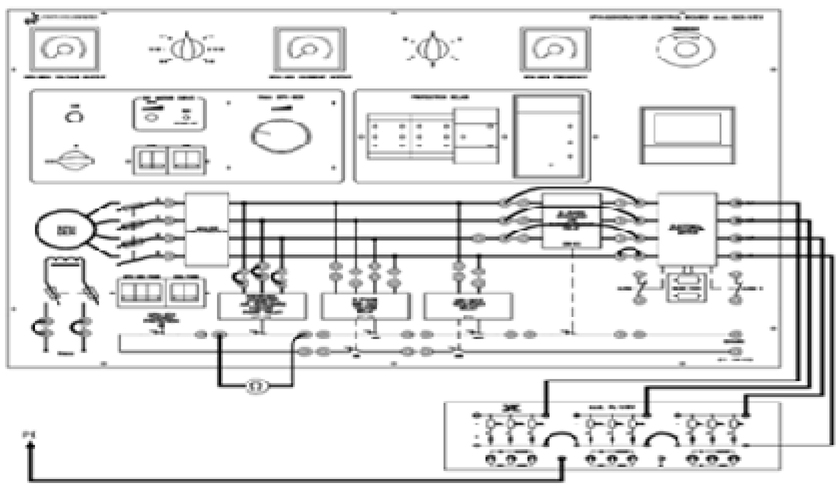
Very Important Note for each part of the exp.

You must be attention to the value of line voltage on the generator terminals to be constant to 400V because when the load is disconnected, Sure that this voltage will increase so you must quickly decrease the excitation voltage of the generator to obtain terminal voltage 400 V constant.

Experiment procedures

Part one: symmetry relay

1. First of all remove all the jumpers enabling the protection relays.
2. Insert three jumpers into the terminals set to power the relay for phase sequence, phase lacking and voltage asymmetry as shown in figure #1
3. Connect an ohm meter to the enable contact of that relay as shown



Connections on the board GCB-1/EV
Operation test of the relay for phase sequence , phase lacking and voltage asymmetry

Figure #1

4. Disconnect one of the three phases, checking continuity in the multimeter and counting delay time and notice when the relay interrupt the circuit continuity after some delay, which recorded in the following table (table#1)

Phase values of voltages			Time delay (Sec.)	Measured time (Sec.)
V1 (volt)	V1 (volt)	V3 (volt)		

(Table#1)

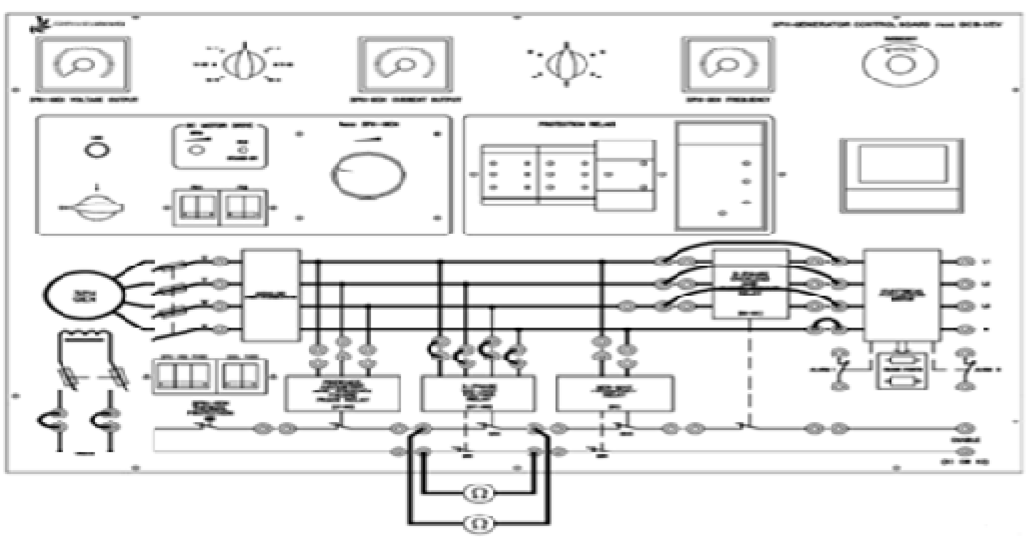
5. Another exercise is the asymmetry of the phases. put unbalanced load and recorded line currents and delay time as following table (table#2).

Percent of asymmetry	Line current (Amp)			Time delay(Sec.)	Measured time (Sec.)
	I_A	I_B	I_C		
5%				5 sec	
7.5%				5 sec	
10%				5 sec	

(Table#2)

<u>Part two:</u> max/min voltage relay

1. Remove jumpers of asymmetry relay and connect Max/Min voltage relay to power as shown in figure #2.



Connections on the board GCB-1/EV
Operation test of the max/ min three phase voltage relay
Figure #2

2. Choose the value of percent of max / min voltage and delay time and then decrease the voltage by adding some loads and measure the delay time at different minimum values of voltages and record the data in table #3.

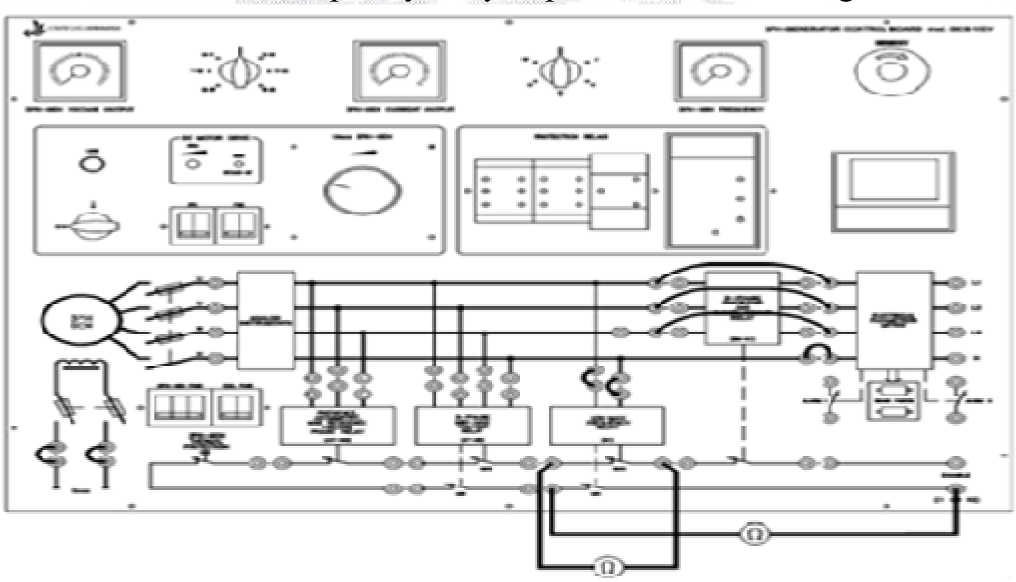
3. Choose the value of percent of max / min voltage and delay time and then increase the voltage by increasing the excitation voltage and measure the delay time at different maximum values of voltages and record the data in table #3:

Percent of Max/min voltage	Measured voltage (V)	Time delay (sec.)	Measured time (sec.)
Max of 106%		5 sec	
Max of 110%		5 sec	
Min of 94%		5 sec	
Min of 86%		5 sec	

(Table #3)

Part three: max/min frequency relay

1. As in the previous part removed jumpers of max/min voltage relay and connect Max/Min frequency relay to power as shown in figure# 3



Connections on the board GCB-1/EV
Operation test of the max/min frequancy relay
Figure #3

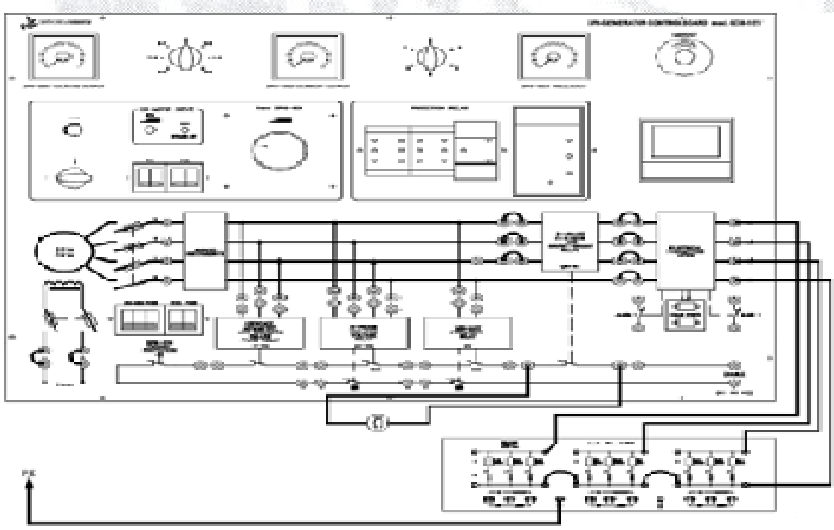
2. fixed the delay time on 3 sec and varied the frequency using RPM potentiometer once for maximum frequency and another for min frequency as shown in table #4

Percent of adjustment f	Frequency (Hz)	Delay time (sec.)	Measured time (sec.)
+10%		3	
+20%		3	
+30%		3	
-10%		3	
-20%		3	
-30%		3	

(Table #4)

<u>Part three:</u> over current and short circuit relay

1. As in the previous part remove jumpers of Max/Min frequency relay and connect over current and short circuit relay to power as shown in figure# 4



Connections on the board GCB-1/EV
Operation test of the three phase ammetric relay with overload function with fixed intervention time
Figure #4

2. Chose and adjust this relay with the following project data:
   Overload threshold = 1 Amp and intervention delay = 5 s;

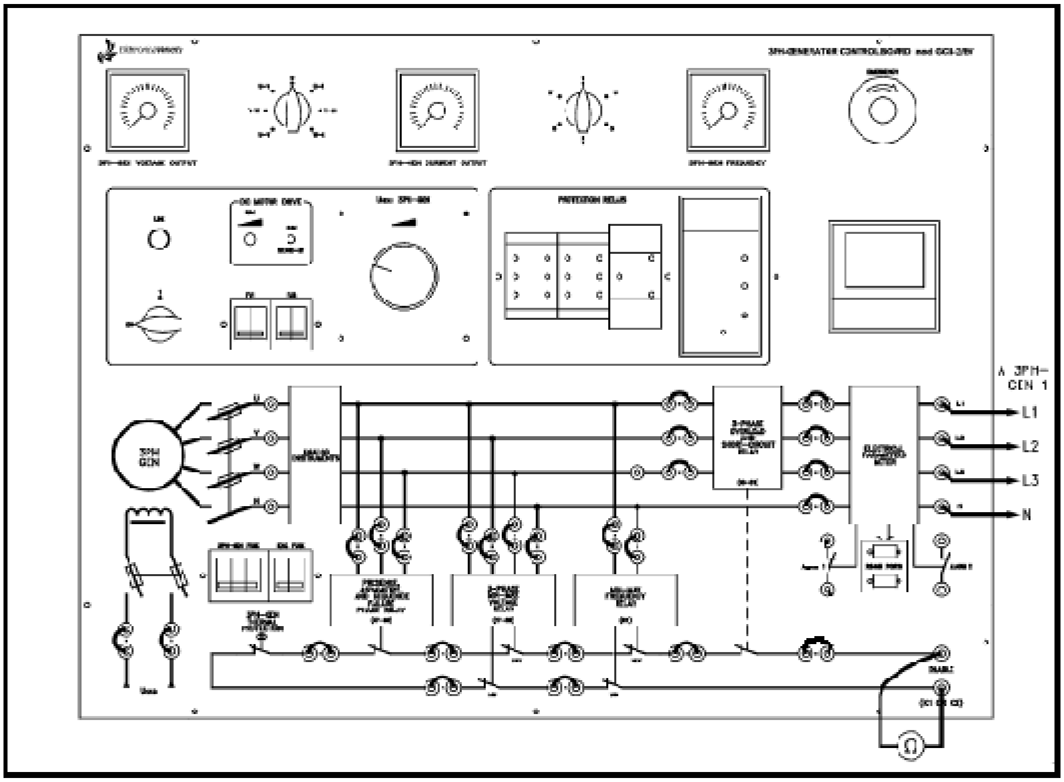
3. Increase the value of the load by adding some resistors and obtain the value of the load current and the delay time when the intervention occurs that is when the ohmmeter shows disconnection of the relays enable contact
   Try to do that for some different adjustment current and time of intervention and tabulate your results in table #5

Adjusting current (Amp)	Adjusting time (sec)	Measuring current (Amp)	Measuring time (sec.)

Table#5

Part five: overall protection relay

1. In order to activate the over all protection relays you should make the connection of the generator control board as shown in the following circuit (**figure#5**).



Figure#5

2. Also you must test each one of these protection relays alone when you operate the generator and load it with a certain load. To do this successfully make the time delay of the relay you want to test it smaller than the time delay of the other protection relay and notice how that relay will cut off the power comes from the generator to the load.
3. Repeat step 2 to test each one of protection relays alone

<u>Remember This Important Note:</u>

<u>You must be attention to the value of line voltage on the generator terminals to be constant to 400V because when the load is disconnected, this voltage will increased so you must quickly decrease the excitation voltage of the generator to obtain terminal voltage 400 V constant.</u>

In this part connect all of the protection relays and get three points of power without losing continuity of any one of the relays. These three points are recorded in table #6:

Load R_L (Ω)		Voltage (V)	Current (A)	Power (W)
A	720	400		
B	360	400		
AB	240	400		

(Table #6)

Write down your conclusions:

Experiment #5

T.L performance under different load conditions

Objectives :

1. To study the behavior of T.L under different load conditions (voltage drop , currents and efficiency of T.L) .
2. To notice the flow of real and reactive power under different types of loads at T.L.

THEORY:

The power losses and voltage drops of a transmission line are defined under load when the root-mean-square values of the electric quantities are measured at both the starting and destination stations. The simulator will refer to lines with symmetrical conductors and balanced load. This statement enables to imagine the electric diagram shown in the fig. 1.

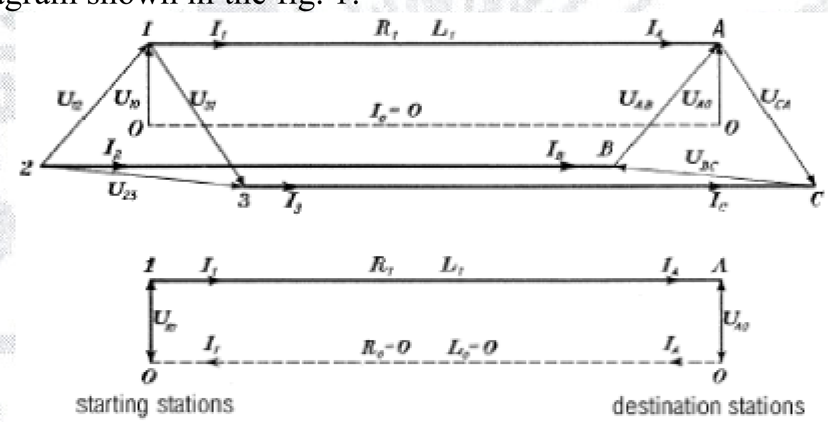


Fig.1 - Equivalent diagram of a three-phase line with symmetrical conductors and balanced load

The diagram of the fig. 1 also includes a fictitious neutral conductor, equidistant from the three active conductors: this gives the possibility of leading the study of the operating characteristics of the three-phase line to a mere single-phase circuit consisting of only one of the three line wires and of an ideal return wire without resistance nor inductance. All that is due to the fact that the neutral wire of a three-phase line with balanced load would not be crossed by any current and consequently it could not provoke any ohmic nor inductive voltage drop.

The line defined s indicated above would show:

1. the total power **Ps=3xVsxIs.Cosθ** at the origin of the line.
2. the total power **PR=3xVRxIR.Cosθ** at the end of the line.
3. the total loss **P= Ps- PR**

4. the performance in load condition **$\eta = PR / Ps = 1\text{-}P/ Ps$**
5. the percent loss **$P\% = 100 \times P/ Ps$**
6. the percent voltage drop **$\Delta V = 100 \times (Vs\text{-}VR)/ Vs$**
7. the percent current variation **$\Delta I = 100 \times (Is\text{-}IR)/Is$**

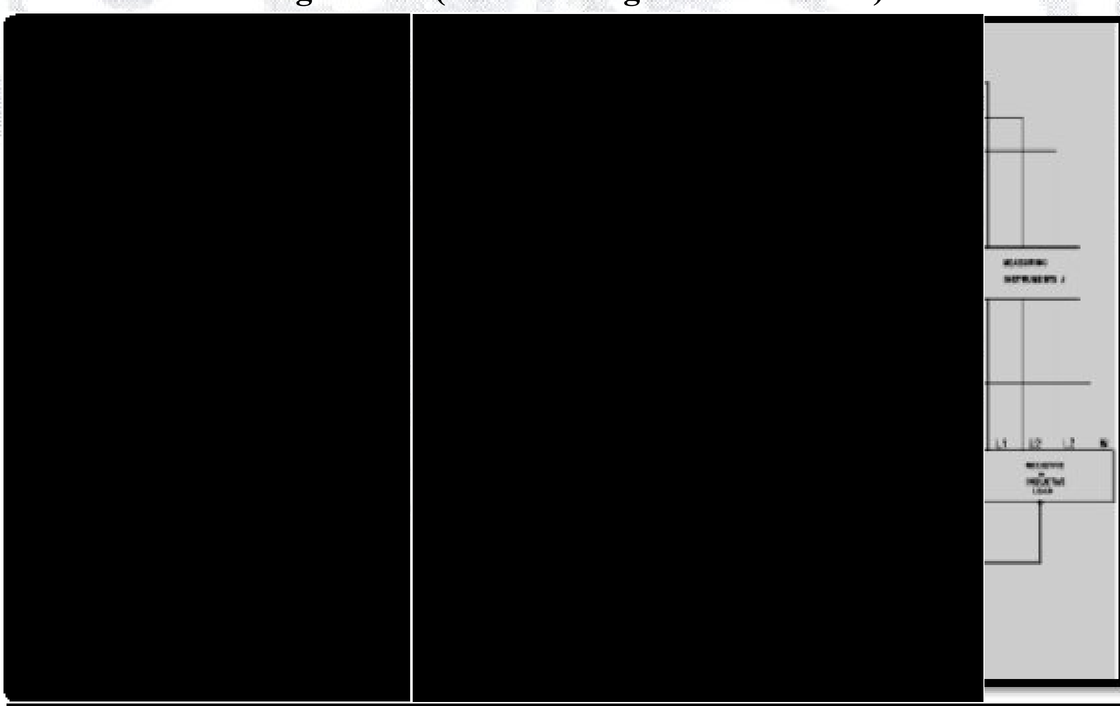
Equipments required (Apparatuses):

1. Simulator for electric lines mod. SEL.1/EV.
2. Variable 3-phase power supply mod. AMT-3/EV.
3. Three phase transformer mod. P 14A/EV
4. Set of jumpers for electrical connection.
5. 2 digital instruments for measurements mod. AZ – VIP.
6. Variable resistive load mod.RL-2/EV.
7. Variable inductive load mod.IL-2/EV.
8. Variable capacitive load mod.CL-2/EV.

Experimental procedure:

Make the connections of the transmission line circuit as shown in the following figures (**Figure #1& Figure #2).**

Figure #1 (The line diagram connection)



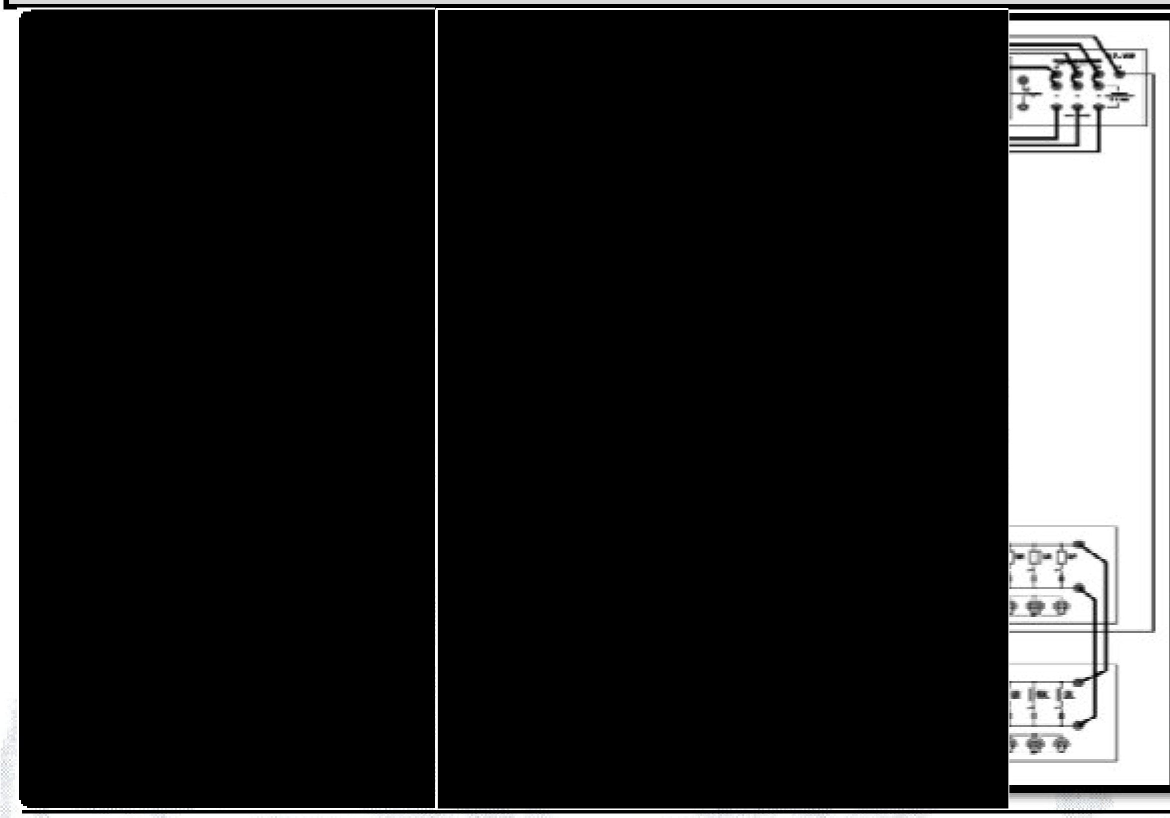


Figure #2 (The circuit connection)

<u>Part I</u> *:* Performance of T.L under resistive load (light, natural and heavy loads).

1. Turn on **(T.L-2)** alone with R=35 Ω , L=0.072 H , C=0.1 μF , you may remove jumpers from **(T.L-1)** to ensure it is disconnected
2. Notice that (Y) connection of capacitors refer to [capacitance with ground] and(Δ) connection refer to capacitance between lines
3. Connect the 2 electronic meters at the sending and receiving ends
4. Connect the variable 3-phase power supply through (Y-Y) transformer and adjust it to keep the voltage 380 v at the sending end of the T.L
5. Connect the receiving end with a resistive load.
6. Adjust the power supply at **350 v**
7. Enable (T.L-2)
8. Take the readings at the sending and receiving ends at different load steps as **in the table #1:**

RL (Ω)		V_s (V)	I_s (Amp)	P_s (W)	Q_s (VAR)	PF_s	V_R (V)	I_R (Amp)	P_R (W)	Q_R (VAR)	PF_R
No load	O.C	350									
A	720	350									
B	360	350									
A//B	240	350									
C	180	350									
A//C	144	350									

Table#1

9- Notice that the (-) sign of Q means that the reactive power is generated by the line

Part II : Performance of T.L under inductive load .

1. Adjust the sending end voltage to **380 v**
2. Set the line parameters to: **R=8.9 Ω , C=0.1 µF , L=0.035H , Length=25km**
3. Connect the inductive load to receiving end of T.L and vary it in steps and take your results as in the **table #2** :

L (mH)		V_s (V)	I_s (Amp)	P_s (W)	Q_s (VAR)	PF_s	V_R (V)	I_R (Amp)	P_R (W)	Q_R (VAR)	PF_R
No load	O.C	380									
A	230	380									
B	115	380									
A//B	77	380									

Table#2

Part III : Performance of T.L under capacitive load .

1. Adjust the sending end voltage of the T.L at 380 v
2. Connect capacitive load to receiving end of T.L and vary it in steps and take your results as in the **table #3** :

C_L (µF)		V_s (V)	I_s (Amp)	P_s (W)	Q_s (VAR)	PF_s	V_R (V)	I_R (Amp)	P_R (W)	Q_R (VAR)	PF_R
No load	O.C	380									
A	4.5 µF	380									
B	9 µF	380									
C	18 µF	380									

Table#3

Part IV : Performance of T.L under RL and RC loads .

1. The sending end voltage should be kept at 380 v
2. Connect a variable resistive inductive load to receiving end of T.L and vary it in steps and take your results as in the **table #4** :

RL(Ω) //L(mH)	V_s (V)	I_s (Amp)	P_s (W)	Q_s (VAR)	PF_s	V_R (V)	I_R (Amp)	P_R (W)	Q_R (VAR)	PF_R
No load	**380**									
A // A **720 Ω //230 mH**	**380**									
A // B **720 Ω //115 mH**	**380**									
A // (A//B) **720 Ω //77 mH**	**380**									

Table #4

3. The sending end voltage should be kept at 380 v
4. Connect a variable resistive capacitive load to receiving end of T.L and vary it in steps and take your results as in the **table #5** :

RL(Ω) //C(μF)	V_s (V)	I_s (Amp)	P_s (W)	Q_s (VAR)	PF_s	V_R (V)	I_R (Amp)	P_R (W)	Q_R (VAR)	PF_R
No load	**380**									
A // A **720 Ω//4.5 μF**	**380**									
A // B **720 Ω//9 μF**	**380**									
A // C **720 Ω//18 μF**	**380**									

Table #5

Calculate the voltage drop, total power losses and performance (efficiency) of the transmission line

For pure resistive load: the calculations of voltage drop, total power losses and performance of transmission line are tabulated in table #6

RL (Ω)		V_s (V)	I_s (Amp)	V_R (V)	I_R (Amp)	P_s (W)	P_R (W)	ΔV $V_s - V_R$ (V)	P_{losses} $P_s - P_R$ (W)	η
No load	O.C	350								
A	720	350								
B	360	350								
A//B	240	350								
C	180	350								
A//C	144	350								

Table #6

For pure inductive load: the calculations of voltage drop, total power losses and performance of transmission line are tabulated in table #7

L (mH)		V_s (V)	I_s (Amp)	V_R (V)	I_R (Amp)	P_s (W)	P_R (W)	ΔV $V_s - V_R$ (V)	P_{losses} $P_s - P_R$ (W)	η
No load	O.C	380								
A	230	380								
B	115	380								
A//B	77	380								

Table #7

For pure capacitive load: the calculations of voltage drop, total power losses and performance of transmission line are tabulated in table #8

C_L (µF)		V_s (V)	I_s (Amp)	V_R (V)	I_R (Amp)	P_s (W)	P_R (W)	ΔV $V_s - V_R$ (V)	P_{losses} $P_s - P_R$ (W)	η
No load	O.C	380								
A	4.5 µF	380								
B	9 µF	380								
C	18 µF	380								

Table #8

For resistive inductive load: the calculations of voltage drop, total power losses and performance of transmission line are tabulated in table #9

RL(Ω) //L(mH)	V_s (V)	I_s (Amp)	V_R (V)	I_R (Amp)	P_s (W)	P_R (W)	ΔV $V_s - V_R$ (V)	P_{losses} $P_s - P_R$ (W)	η
No load	380								
A // A 720 Ω //230mH	380								
A // B 720Ω //115mH	380								
A // (A//B) 720 Ω //77mH	380								

Table #9

For resistive capacitive load: the calculations of voltage drop, total power losses and performance of transmission line are tabulated in table #10

$R_L(\Omega)$ //C(μF)	V_s (V)	I_s (Amp)	V_R (V)	I_R (Amp)	P_s (W)	P_R (W)	ΔV $V_s - V_R$ (V)	P_{losses} $P_s - P_R$ (W)	η
No load	380								
A // A 720 Ω//4.5 μF	380								
A // B 720 Ω//9 μF	380								
A // C 720 Ω//18 μF	380								

Table #10

<u>At the same graph sketch the following relationships for all load conditions</u>

1. **Vs** as function of **Is** for different load conditions.
2. V_R as function of I_R for different load conditions.
3. ΔV as function of I_R for different load conditions.
4. **η** as function of I_R for different load conditions.

Question #1

Explain the variation of reactive power from negative sign to positive sign at the sending end as the load current increases for resistive load condition

Question #2

For, the resistive load condition, can you observe the light, natural and heavy load conditions?

Question #3

What is the effect of increasing the load current on the receiving end voltage for different load conditions?

Question #4

What is the affect of increasing the load current on the efficiency of the TL for different load conditions?

Question #5

Can you module the medium TL?

Question #6

Draw the phasor diagrams for medium length transmission lines operating at different load conditions

Question #7

What is the characteristic impedance of the line used in part I|?

Question #8

What is the ratio of the current under natural load to the rated current of the line which is equal to 1 Amp?

Write down your conclusions

Experiment #6

Parallel operation of two AC generators

Objectives:

1. To curry out the connections and the sequence of operations for the parallel connection between synchronous generators.
2. To demonstrate the effects of the oscillation in the parallel connection of two generators.
3. To include the protection relays in the power generating systems.
4. To detect the system data with the digital power analyzer.
5. To adjust the system frequency and the real power sharing.
6. To adjust the system terminal voltage and the reactive power sharing.

Abstract:

In the system of a generator connected in parallel with another one of the same size, the basic constraint is that the sum of the real and reactive powers supplied by the two generators must be equal the P and Q demanded by the load. The system frequency is not constrained to be constant, and neither is the power of a given generator constrained to be constant.

The total power P_{tot} (which is equal to P_{load}) is given by

$$\mathbf{P_{tot} = P_{load} = P_{G1} + P_{G2}}$$

And the total reactive power is given by

$$\mathbf{Q_{tot} = Q_{load} = Q_{G1} + Q_{G2}}$$

In this report we will study the influence of the governor set points on both frequency and power flow, and the influence of the field current on both terminal voltage and reactive power flow.

Also we will explore the requirements for paralleling AC generators.

Throughout this report, concepts will be illustrated with simplified house diagrams.

Equipments required (Apparatuses):

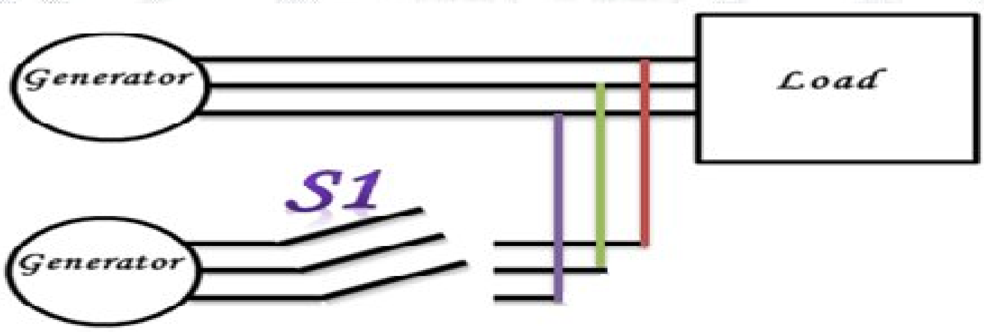
1. Generator parallel board mod. PCB-2/EV.
2. 2 Control boards for the generating set mod. GCB-2/EV.
3. 2 Synchronous generator-motor units mod. MSG-1/EV.
4. Variable resistive load mod. RL-2/EV or RL-2A/EV.
5. Variable inductive load mod. IL-2/EV .
6. Set of cables-jumpers for electrical connections.

Introduction:

Figure 1 shows a synchronous generator G1 supplying power to a load, with another generator G2 about to be paralleled with G1 by closing the switch S1.

If the switch is closed arbitrarily at some moment, the generators are liable to be severely damaged, and the load may lose power. If the voltages are not exactly the same in each conductor being tied together, there will be a very large current flow when the switch is closed. To avoid this problem, each of the three phases must have exactly the same voltage magnitude and phase angle as the conductor to which it is connected. In other words, the voltage in phase a must be exactly the same as the voltage in phase a', and so forth for phases b-b' and c-c'. To achieve this match, the following paralleling conditions must be met:

1- **The rms line voltage of the two generators must be equal.**
2- **The two generators must have the same phase sequence.**
3- **The phase angles of the two ' a ' phases must be equal.**
4- **The frequency of the new generator, called the oncoming generator, must be slightly higher than the frequency of the running system.**



Figure# 1

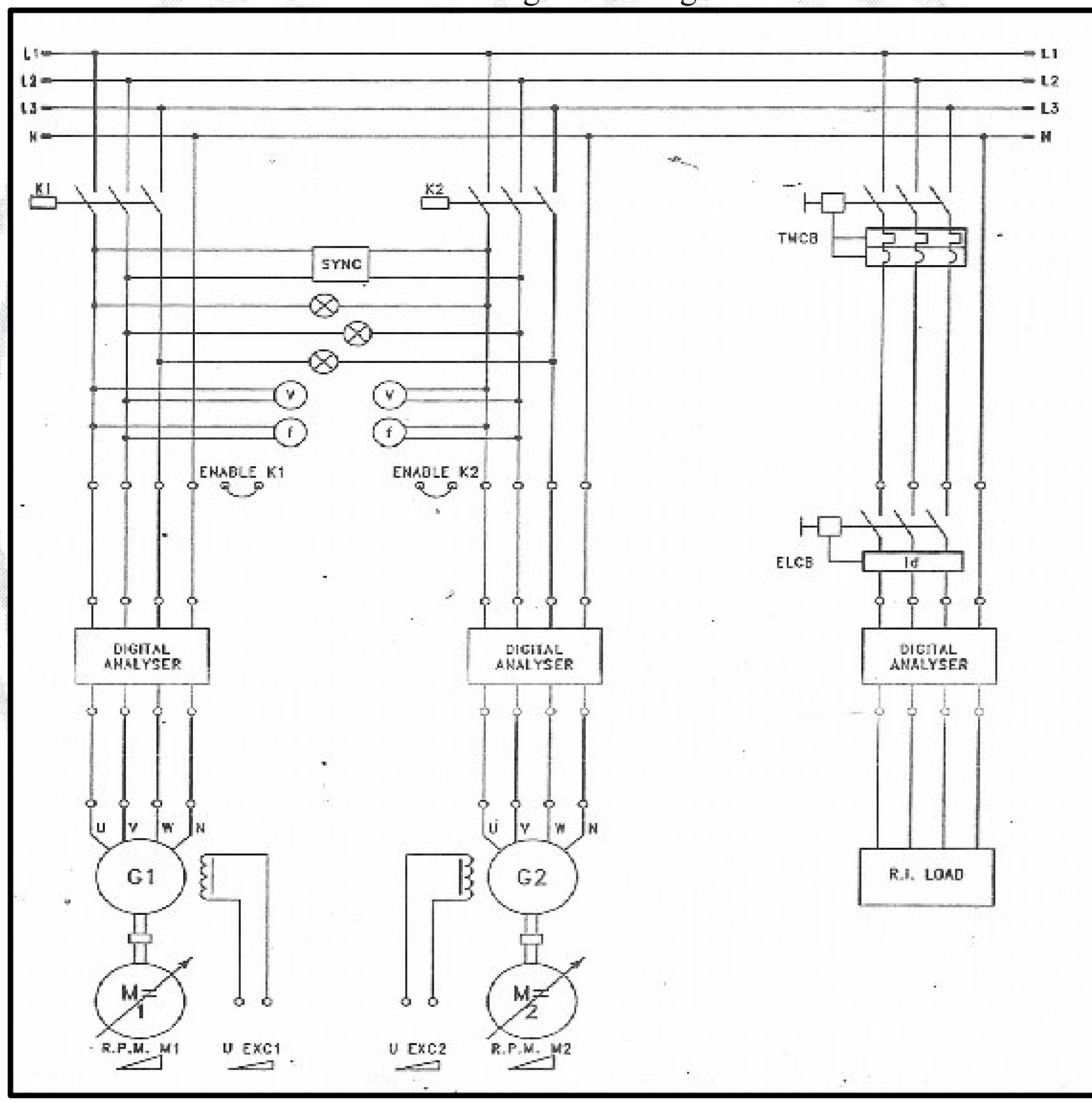
(A generator being paralleled with another generator).

In real systems containing generators of approximately equal size, the governor set points affect both frequency and power flow, and the field current affects both terminal voltage and reactive lower flow, this experiment will illustrate that.

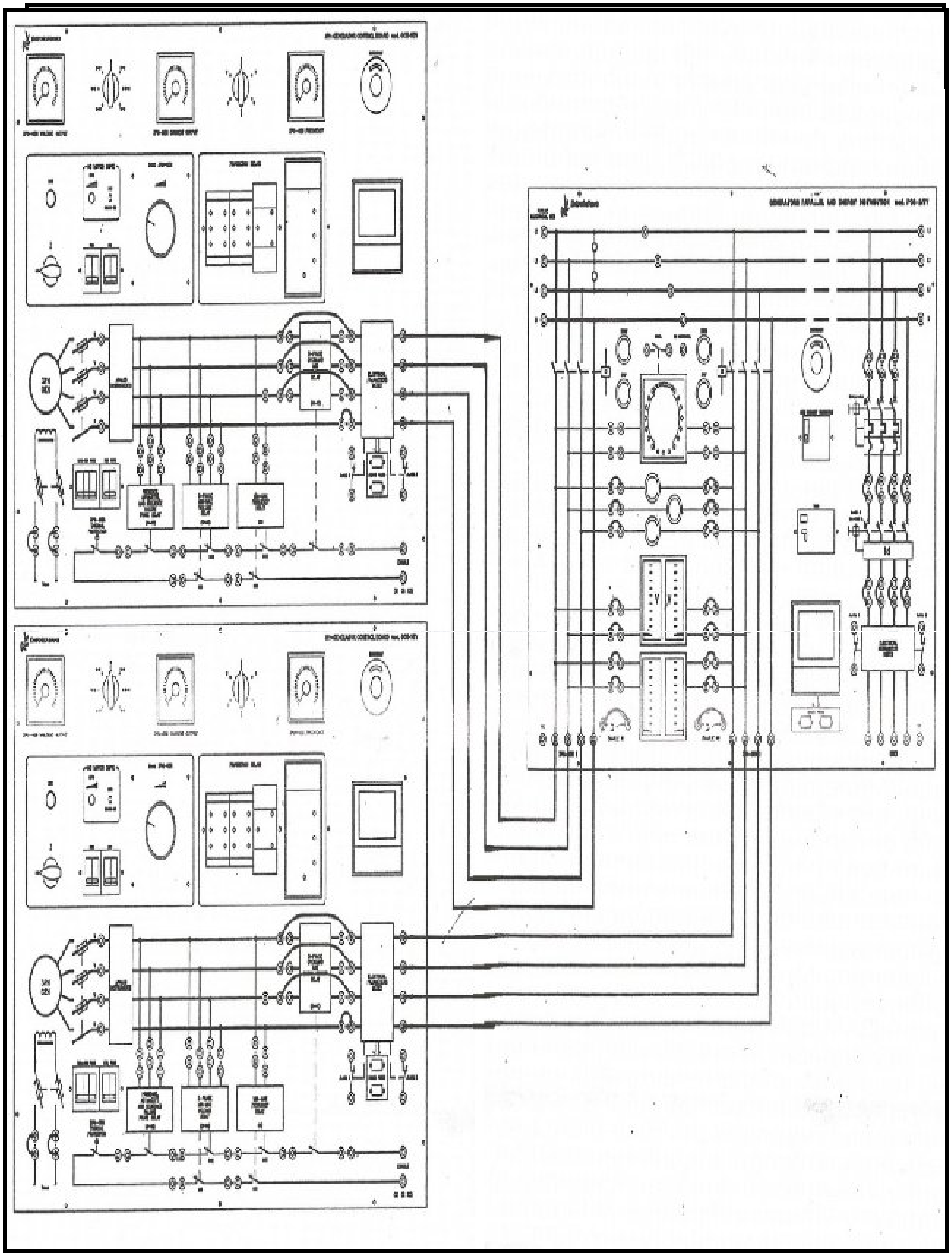
Experiment Procedure:

The Conditions Required for Paralleling

1. Connect the circuit shown in the figure#2 & figure#3.



Figure#2: Electrical reference diagram for the parallel connection of two synchronous generators.



Figure#3: Electrical Configuration for the parallel connection of two synchronous generators.

2. Activate the prime mover of the **synchronous generator#1** and adjust the speed to obtain the rated frequency **(f1 =50Hz)** and increase the field voltage to obtain nominal terminal line to line voltage **(V_{T1} =400 volt)**.
   Then press the **START button of the first contactor K1** to connect the triad of voltages output by the generator1, with the main bars.
3. Activate the prime mover of the **synchronous generator#2** and adjust the speed to obtain the rated frequency **(f2 =50Hz)** and increase the field voltage to obtain nominal terminal line to line voltage **(V_{T2} =400 volt)**.

Very important note:

You must make sure that the second contactor K2 remains open until reaching the stage of synchronization.

Ideal moment for carrying out the parallel connection under no load condition.

1- Adjust the field current of the generator#2 until its terminal voltage is equal to the line voltage of the generator#1 (the running system).
2- Check the phase sequence by using the three-light-lam method. If all three lams get bright and dark together. Then the systems have the same phase sequence.
3- Adjust the frequency of the generator#2 to be approximately equal to the frequency of the generator#1.
4- Now notice the three lamps and the synchroscope lights

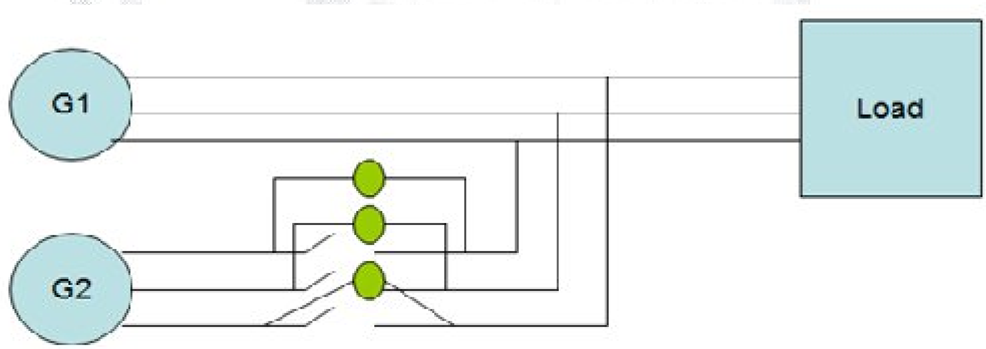


Figure # 4

(The three-light-lamps method for checking phase sequence).

In the exact moment when the 3 lamps are actually off and the LED synchroscope is lighting in the green zone, at this moment **START the button of contactor K2** to lead the generators to be connected in parallel with the first generator (generator #1).

Part1: <u>The effect of changing the prim mover speed and excitation current of one generator at no load.</u>

1 . After making the parallel operation of the two generators correctly and at no load conditions take the values of frequencies, real powers of generator #1, generator #2 and the system tabulate your data in table # 1

2 . Increase the frequency for generator#2 and fill table#1with three different values of frequency.

f1 (Hz)	f2 (Hz)	$f_{sys)}$ (Hz)	P1 (watt)	P2 (watt)	P_{sys} (watt)

Table#1

3. Decrease the frequency of generator #2 to be the same with the first value of operation and then adjust the excitation current of generator#2 to change the voltage, take the values of terminal voltages, reactive powers of generator #1, generator #2 and the system tabulate your data in table # 2

V1 (v)	V2 (v)	$V_{(sys)}$ (v)	Q1 (VAR)	Q2 (VAR)	Q_{sys} (VAR)

Table#2

4 . Decrease the excitation current of generator#2 to return back to normal operation values.

Part2 (A): The effect of changing the prime mover speed of one generator upon the system frequency and the real power sharing between the two generators.

1. Follow the parallel operation steps as mentioned before and, take care to do that correctly. Try to let the system do that automatically by setting the switch existing over the synchroscop to the automatic mode after making the all the necessary adjustments of both generators to be synchronized.
2. Add a three phase resistive inductive load to the system terminals and take the required measurements in table#3
3. Gradually, increase the frequency for generator#2 and fill the table#3.

R=360Ω (switch B) & L=1.15 H(switch B)								
f1 (Hz)	f2 (Hz)	f_{sys} (Hz)	P1 (watt)	P2 (watt)	P_{load} (watt)	I1 (Amp)	I2 (Amp)	I_L (Amp)

Table#3

Question#1:

Explain graphically by drawing house diagrams of power – frequency characteristic the effect of adjusting the frequency of generator#2?

Part2 (B): The effect of increasing the prime mover speed of generator#2 while decreasing it on generator#1 on the system frequency and the real power sharing between the two generators

4. Return back to the normal operation values and keep the two generators to be synchronized with each other.
5. Increase the frequency of generator #2 and decrease the frequency of generator #1in a small amount with the same value of resistive inductive load an tabulate your results in table #4

R=360Ω (switch B) & L=1.15 H(switch B)								
f1 (Hz)	f2 (Hz)	f_{sys} (Hz)	P1 (watt)	P2 (watt)	P_{load} (watt)	I1 (Amp)	I2 (Amp)	I_L (Amp)

Table#4

Question#2:

How can the power sharing of the power system can be adjusted independently of the system frequency?

Question#3:

Explain graphically the effect of adjusting the frequency of both generators? (Increasing the frequency of generator#2 and decreasing the frequency of generator#1)

Part2 (C): The effect of changing the prime mover speed of both generators on the system frequency and the real power sharing between the two generators

6. Return back the normal operation values and keep the two generators to be synchronized with each other.
7. Increase or decrease the frequency of both generator in a small amount with the same value of resistive inductive load and tabulate your results in table #5

R=360Ω (switch B) & L=1.15 H(switch B)								
f_1 (Hz)	f_2 (Hz)	f_{sys} (Hz)	P_1 (watt)	P_2 (watt)	P_{load} (watt)	I_1 (Amp)	I_2 (Amp)	I_L (Amp)

Table#5

Question#4:

Explain graphically the effect of increasing or decreasing the frequency of both generators at the same time? What do you notice about that?

Part3(A) The effect of adjusting the excitation current of one generator on the reactive power sharing and the terminal voltage

1. Return back to the normal operation values and keep the two generators to be synchronized with each other.
2. Add a three phase resistive - inductive load at the system terminals and take the required measurements in table#6
3. Gradually, increase the excitation voltage of generator#2 and fill the table#6.

R=360Ω (switch B) & L=1.15 H(switch B)					
V_{G1} (v)	V_{G2} (V)	V_{sys} (v)	Q_{G1} (VAR)	Q_{G2} (VAR)	Q_{load} (VAR)

Table#6

Question#5:

What happens if the field current of generator#2 is increased? Explain that graphically by drawing the house diagrams of voltage- reactive power characteristic?

Part3(B) The effect of increasing or decreasing the excitation current on both generators on the reactive power sharing and the terminal voltage.

4. Return back to the normal operation values and keep the two generators to be synchronized with each other.
5. With the same resistive inductive load adjust the excitation current of both generators (increase or decreasing the excitation voltage of both generators) in a small amount and tabulate your results in table #7

R=360Ω (switch B) & L=1.15 H(switch B)					
V_{G1} (v)	V_{G2} (V)	V_{sys} (v)	Q_{G1} (VAR)	Q_{G2} (VAR)	Q_{load} (VAR)

Table#7

Question#6:

How can the terminal voltage of the power system can be adjusted independently of the reactive power sharing? Explain that graphically by drawing the house diagrams of voltage- reactive power characteristic?

Part3(B) The effect of increasing the excitation current on generator#2 while decreasing it on generato#1 on the reactive power sharing and the terminal voltage.

6. Return back to the normal operation values and keep the two generators to be synchronized with each other.
7. With the same resistive - inductive load increase the excitation voltage of generator #2 and decrease the excitation voltage of generator #1in a small amount keep the terminal voltage constant and tabulate your results in table #8

R=360Ω (switch B) & L=1.15 H(switch B)					
V_{G1} (v)	V_{G2} (V)	V_{sys} (v)	Q_{G1} (VAR)	Q_{G2} (VAR)	Q_{load} (VAR)

Table#8

Question#7:

How can the reactive power sharing of two generators be adjusted independently of the terminal voltage? Explain that graphically by drawing the house diagrams of voltage- reactive power characteristic??

Write down your conclusions.

Experiment#7

Series and parallel operations of power transmission lines under load

Objectives:

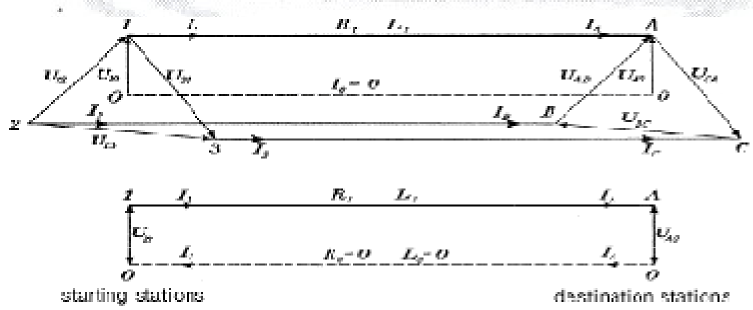
1. Study the series and parallel operation of transmission lines.
2. Understanding the effects of transmission line capacitance.
3. To understand the effects of T.L length on the voltage drop and reactive power.
4. To understand the effects and results if one line has been lost in parallel operation.

Equipments required:

1. Simulator of electric lines mod. SEL-1/EV.
2. Variable three-phase power supply mod. AMT-3/EV.
3. Three-phase transformer mod. P 14A/EV.
4. Set of leads/jumpers for electrical connections.
5. 2 digital instruments for measuring the parameters of electric energy in three-phase systems mod.
6. Variable resistive load mod. RL-2/EV.
7. Variable inductive load mod. IL-2/EV.
8. Variable capacitive load mod. CL-2/EV.

Part I: Series operation of transmission line under load

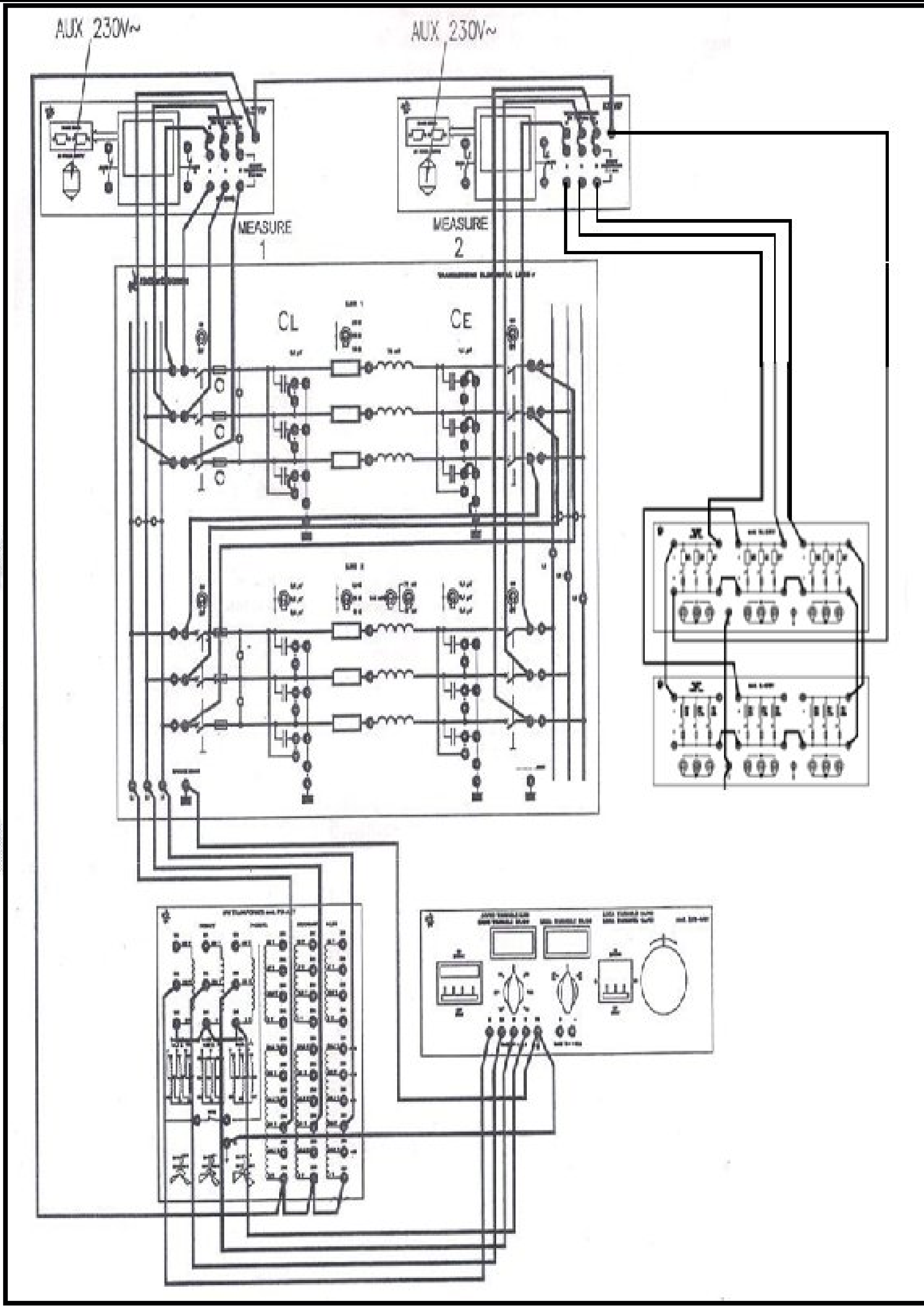
The power losses and voltage drops of a transmission line are defined under load when the root- mean-square values of the electric quantities are measured at both the starting and destination stations. Those lines have symmetrical conductors and balanced load. This statement enables to imagine the electric diagram shown in the following figure (figure#1).



(Figure#1)

Preparing the experiment :

1. Consider two lines with equal current-carrying capacity, but different length.
2. For this exercise, **LINE 1 is with the constants**:
   Resistance = 18 Ω;
   Inductance = 0.072 H;
   Length = 50 km;
   Section = 50 mm2 – conductor of copper;
   And LINE 2 with the constants:
   Resistance = 8.9 Ω;
   Inductance = 0.036 H;
   Length = 25 km;
   Section = 50 mm2 – conductor of copper;
3. Connect only the jumpers at the origin of LINE 1 and those of the end of LINE 2.
4. Connect the end terminals of LINE 1 (terminals immediately at the right of the breaker) with the starting terminals of the LINE 2 (terminals at the left of the breaker), via some leads, to carry out the series connection of the two lines.
5. Make sure that the origin and end breakers of both the lines are OFF.
6. Do not connect the jumpers with the capacitors supposing that the parameter of capacitance is negligible.
7. Connect the variable three phase power supply mod. AMT-3/EV to the primary of the transformer.
8. Connect the left sending end bus with the secondary of the three-phase transformer so that the ratio is 1:1, and the load with the right receiving end bus of LINE2.
9. By the end of this process you will obtain the electric diagram shown in the figure# 2 shown.



Figure#2

Section 1: (A) Pure resistive load (Without T.L capacitance)

1. Make sure that T.L capacitors are not connected and that all loads are off.
2. Enable and adjust the supply voltage of the line at **380 V**at the sending end.
3. Turn the origin and end breakers of LINE 1 ON, in sequence, then turn the origin and end breakers of LINE 2 ON.
4. Insert some load steps of pure resistive load, in sequence and read the electrical quantities on the measuring instruments and write them down in the following table (**table#1**), calculate the voltage drop according to load.

(**CAUTION : DO NOT allow line current to exceed 1 A)**

RL (Ω)	**A**	**B**	**AB**	**C**	**AC**
	720 Ω	**360 Ω**	**240 Ω**	**180 Ω**	**144 Ω**
V_S (v)	380	380	380	380	380
I_S (Amp)					
P_S(watt)					
$P.F_S$					
Q_S (VAR)					
V_{Mid} (v)					
V_R (v)					
I_R (Amp)					
P_R (watt)					
$P.F_R$					
Q_R **(VAR)**					
ΔV (v)					
η					

(Table#1)

Question #1:

Draw and explain the following characteristics:

- V_R versus. I_R
- Q_S versus I_R
- ΔV versus I_R
- η versus I_R

Question #2:

How can the drop voltage across the line be reduced ?

Section 1:(B) Resistive-inductive load (Without T.L capacitance)

1. Make sure that T.L capacitors are not connected and all loads are off.
2. Enable and adjust the supply voltage of the line at 380 V.
3. Turn the origin and end breakers of LINE 1 ON, in sequence, then turn the origin and end breakers of LINE 2 ON.
4. Use one fixed resistive load step in parallel with some load steps of inductive load, in sequence and read the electrical quantities on the measuring instruments and write them down in **table#2**, calculate the voltage drop according to load.

(CAUTION : DO NOT allow line current to exceed 1 A)

RL (Ω)	**A**	**A**	**A**	**A**	**A**
	720 Ω	**720 Ω**	**720 Ω**	**720 Ω**	**720 Ω**
L_L (mH)	**A**	**B**	**AB**	**C**	**AC**
	2.3mH	**1.15mH**	**0.76mH**	**0.57mH**	**0.46mH**
V_S (v)	380	380	380	380	380
I_S (Amp)					
P_S(watt)					
$P.F_S$					
Q_S (VAR)					
V_{Mid} (v)					
V_R (v)					
I_R (Amp)					
P_R (watt)					
$P.F_R$					
Q_R (VAR)					
ΔV (v)					
η					

(Table#2)

Question #3:

Draw and explain the following characteristics:

- V_R versus. I_R
- Q_S versus I_R
- ΔV versus I_R
- η versus I_R

Section 2: (A) Pure resistive load (With T.L capacitance)

1. Connect the left jumpers to represent the capacitance between the active conductors (Delta) (capacitors at the sending end delta connection), then connect the jumpers with the right capacitors to represent the capacitance between active conductors and the ground (Star) (capacitors at the receiving end star connection).
2. Make sure all loads are switched off.
3. Enable and adjust the supply voltage of the line at 380 V.
4. Turn the origin and end breakers of LINE 1 ON in sequence, then turn the origin and end breakers of LINE 2 ON.
5. Insert some load steps of pure resistive load, in sequence and read the electrical quantities on the measuring instruments and write them down in **table# 3**, calculate the voltage drop according to load.

   (**CAUTION : DO NOT allow line current to exceed 1 A)**

RL (Ω)	A	B	AB	C	AC
	720 Ω	**360 Ω**	**240 Ω**	**180 Ω**	**144 Ω**
V_S (v)	380	380	380	380	380
I_S (Amp)					
P_S(watt)					
$P.F_S$					
Q_S (VAR)					
V_{Mid} (v)					
V_R (v)					
I_R (Amp)					
P_R (watt)					
$P.F_R$					
Q_R (VAR)					
ΔV (v)					
η					

(Table#3)

Question #4:

Draw and explain the following characteristics:

- V_R versus. I_R
- Q_S versus I_R
- ΔV versus I_R
- η versus I_R

Question #5:

According to your results, what are the results of light load operation?
Suggest solutions.

Section 2:(B) Resistive-inductive load (With T.L capacitance)

- Connect the left jumpers to represent the capacitance between the active conductors (Delta) (capacitors at the sending end delta connection), then connect the jumpers with the right capacitors to represent the capacitance between active conductors and the ground (Star) (capacitors at the receiving end star connection).
- Make sure all loads are switched off.
- Enable and adjust the supply voltage of the line at 380 V.
- Turn the origin and end breakers of LINE 1 ON in sequence, then turn the origin and end breakers of LINE 2 ON.
- Use one fixed resistive load step in parallel with some load steps of inductive load, in sequence and read the electrical quantities on the measuring instruments and write them down in the **table# 4**, calculate the voltage drop according to load.

(CAUTION : DO NOT allow line current to exceed 1 A)

RL (Ω)	A 720 Ω	A 720 Ω	A 720 Ω	A 720 Ω	A 720 Ω
L_L (mH)	A 2.3mH	B 1.15mH	AB 0.76mH	C 0.57mH	AC 0.46mH
V_S (v)	380	380	380	380	380
I_S (Amp)					
P_S(watt)					
$P.F_S$					
Q_S (VAR)					
V_{Mid} (v)					
V_R (v)					
I_R (Amp)					
P_R (watt)					
$P.F_R$					
Q_R (VAR)					
ΔV (v)					
η					

(Table#4)

Question #6:

Draw and explain the following characteristics:

- V_R versus. I_R
- Q_S versus I_R
- ΔV versus I_R
- η versus I_R

Question #7:

From section I and section II what effects of including T.L capacitance did you notice?

Part II: Parallel operation of transmission line

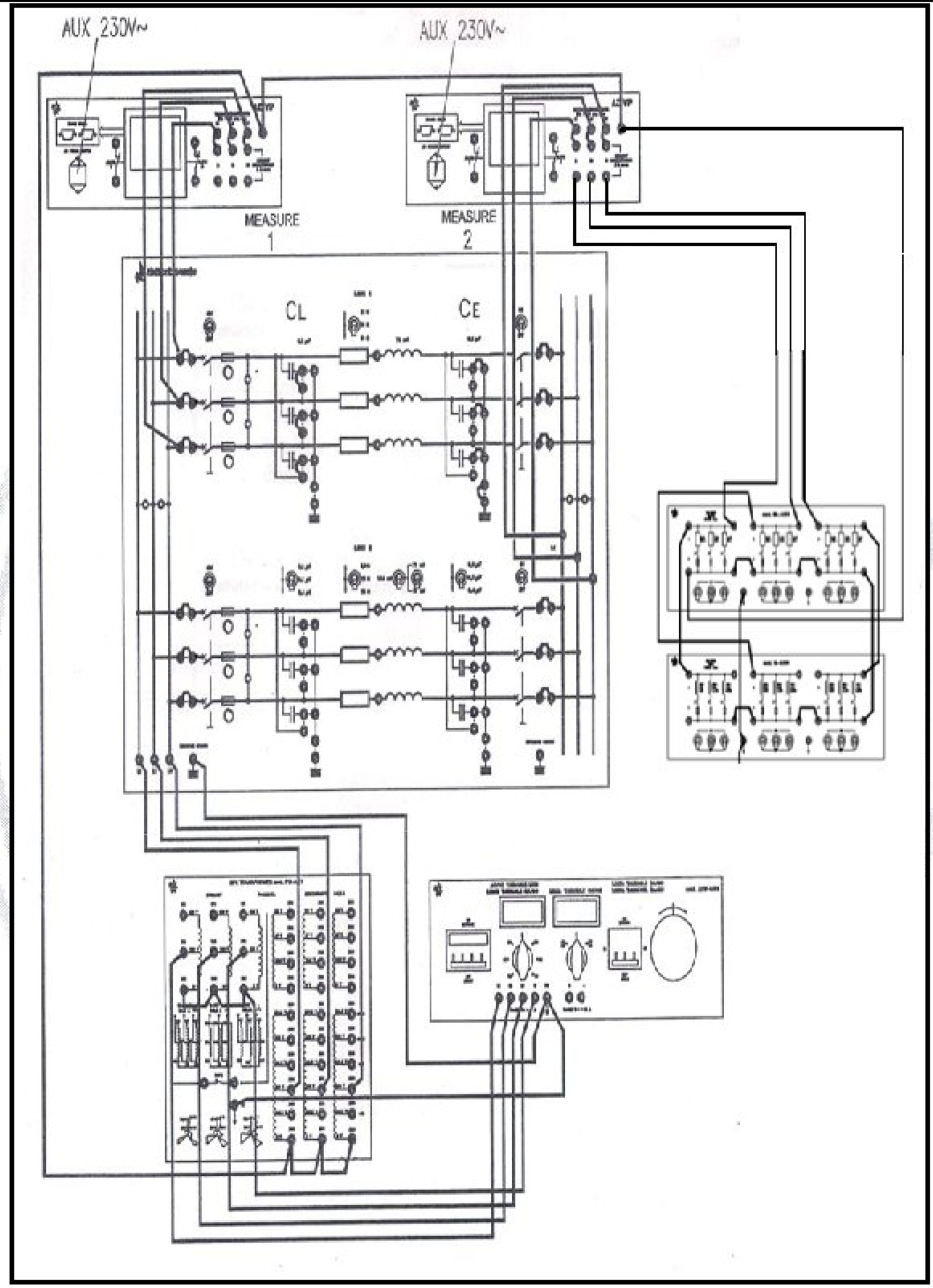
The continuity of the service of distribution of electric energy is very often ensured by "systems" also including spare components that can be enabled, when necessary. This is the reason why, besides the generators and the step-up/step-down transformers, also the main long-distance power lines have a "spare" line, that is a line in parallel that can be used to meet a demand of energy increase, but this type of is also very often used as substitute of the normal line to enable maintenance operations of the power line. Maintenance is generally scheduled and carried out in certain periods when the demand for power is lower. But this spare line can be enabled not only for routine maintenance, but also for faults in the main line. Under this hypothesis, a long-distance power line can always be considered as a single line, apart from the few instants when the lines are in parallel to avoid the interruption of power. This exercise will examine the normal operation of two lines in parallel with each other.

Preparing the experiment:

Consider two equal lines, with the following constants:

Resistance = 18 Ω;
Inductance =0.072 H;
Capacitance = 0.2μF;
Length = 50 km;
Section = 50 mm2 – conductor of copper.

1. Connect all the jumpers at the origin and at the end of the lines, enable both sets of capacitors (those of left hand between phases, and those of right end to ground).
2. Turn the origin and end breakers of both the lines to OFF.
3. Connect the variable three phase power supply mod. AMT-3/EV to the primary side of the three phase transformer.
4. Connect the left sending end bus with the secondary side of the transformer so that the ratio is 1:1, and the load with the right receiving end bus.
5. By the end of this process you will obtain same electrical diagram shown figure #3.



Figure#3

Experimental procedure :

1. Make sure all loads are switched off.
2. Enable and adjust the supply voltage of the line at 380 V.
3. Turn the origin and end breakers of both the lines to ON.
4. Insert pure resistive loads steps sequentially and read the electric quantities on the measuring instruments and write them down in **table#5**; calculate the voltage drop according to load.

(CAUTION:DO NOT allow line current of each line to exceed 1 A)

RL (Ω)	A 720 Ω	B 360 Ω	AB 240 Ω	C 180 Ω	AC 144 Ω	BC 120 Ω
V_S (v)	380	380	380	380	380	380
I_S (Amp)						
P_S(watt)						
$P.F_S$						
Q_S (VAR)						
I_{L1} (Amp)						
I_{L2} (Amp)						
V_R (v)						
I_R (Amp)						
P_R (watt)						
$P.F_R$						
Q_R (VAR)						
ΔV (v)						
η						

Table#5

5. Now disconnect one of the two parallel lines and repeat the measurements and tabulate your result in **table #6**.

(**CAUTION : DO NOT allow line current to exceed 1 A)**

RL (Ω)	**A**	**B**	**AB**	**C**
	720 Ω	**360 Ω**	**240 Ω**	**180 Ω**
V_S (v)	380	380	380	380
I_S (Amp)				
P_S(watt)				
$P.F_S$				
Q_S (VAR)				
V_R (v)				
I_R (Amp)				
P_R (watt)				
$P.F_R$				
Q_R **(VAR)**				
ΔV (v)				
η				

Table #6

Question #8:

Draw and each of the following characteristics for both cases (single line and double line):

- V_R versus. I_R
- Q_S versus I_R
- ΔV versus I_R
- η versus I_R

Question #9:

From your observations try to identify the advantages and disadvantages of parallel operation.

Question #10:

Compare between PART I (series) and PART II (parallel). What difference does the length of T.L have?

Write down your conclusions

Experiment #8

Parallel connection of a three-phase synchronous generator with the public mains

Objectives:

1. To curry out the connections and the sequence of operations for the parallel connection between generator and the mains.
2. To include the protection relays in the power generating systems.
3. To detect the system data with the digital power analyzer.

Abstract:

In the system of a parallel connection of a three-phase synchronous generator with the public mains, the terminal voltage and frequency are constant regardless of the real or reactive power drown from or supply to the infinite bus. The basic constraint in this system is that the sum of the real and reactive powers supplied by the generator and the infinite bus must be equal the P and Q demanded by the load.

The total power $\mathbf{P_{tot}}$ (which is equal to $\mathbf{P_{load}}$) is given by

$$\mathbf{P_{tot} = P_{load} = P_G + P_{I.B}}$$

And the total reactive power is given by

$$\mathbf{Q_{tot} = Q_{load} = Q_G + Q_{I.B}}$$

In this report we will study the influence of the governor set points on the no load frequency of the synchronous generator and therefore on the power sharing, and the influence of the field current on reactive power sharing between the generator and the infinite bus in order to keep both $\mathbf{P_{load}}$ and $\mathbf{Q_{load}}$ constant.

Also we will explore the conditions of parallel connection of a generator with the mains.

Throughout this experiment concepts should be illustrated with simplified house diagrams.

Equipments required (Apparatuses):

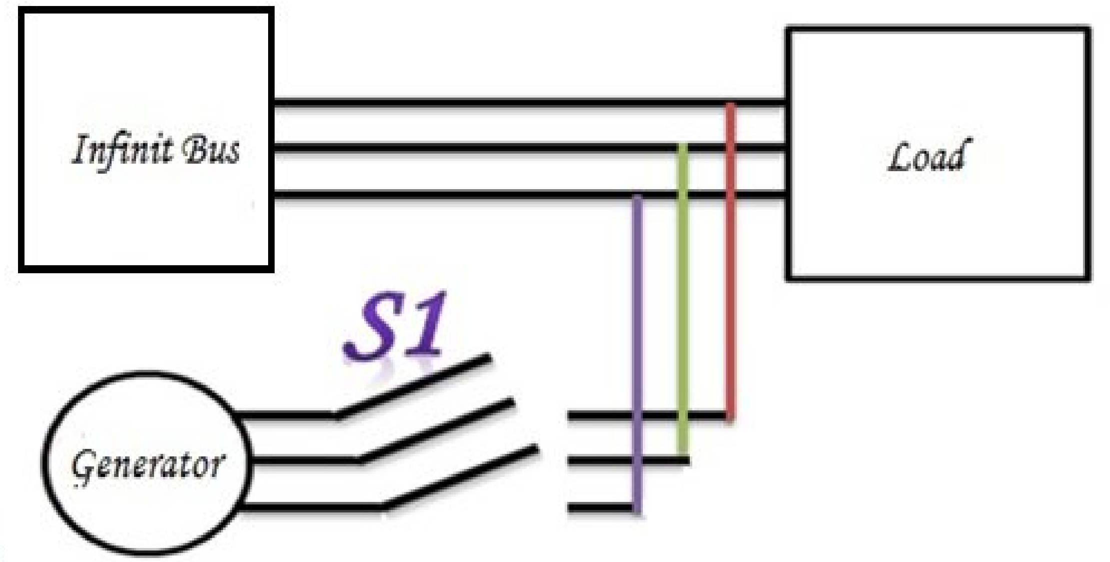
7. Generator parallel board mod. PCB-2/EV.
8. Control boards for the generating set mod. GCB-2/EV.
9. Synchronous generator-motor units mod. MSG-1/EV.
10. Variable power supply mod.AMT-3/EV
11. Variable resistive load mod. RL-2/EV or RL-2A/EV.
12. Variable inductive load mod. IL-2/EV .
13. Set of cables-jumpers for electrical connections.

Introduction:

Some conditions are necessary to be maintained to connect the alternators in parallel. As an example, let s take the case of an alternator with infinite bus, one of which is already connected to the bars. The alternator is to be connected to support the total load, by dividing the active and the reactive load between them.

1- **Equal sequence of phases**: if the line voltages of the synchronous generator G make ABC turn, the three of infinite bus must also make ABC turn. The rotation direction can be checked with different instruments: the first one is an instrument including a three-phase induction motor that must turn in the same direction powered by the bars and by infinite bus. Another method is with 3 lamp, as the one mounted in the system. If the 2 triads do not turn in the same direction, the 3 lamps never light on or off simultaneously. ***To make the triad turn to the other direction, just change the connection of any two phases of infinite bus.***
2- **Equal frequency**: This can be seen in the frequency meters of synchronous generator G and infinite bus that must indicate the same value. Actually, G is set at a little higher speed than infinite bus (this because when "taking load", the prime mover will naturally drop the rpm).***To change the rpm act on the control device (accelerator) of the prime mover of G.***
3- **Equal effective voltages**: this occurs with the voltmeters installed on synchronous generator G and infinite bus. ***To change the voltage of G, you must act on the excitation of G.***
4- **Equal phases**: it means that both triads, synchronous generator G and infinite bus, must coincide to close INT2. This occurs with the synchronoscope, or when the 3 lamps switch off simultaneously. ***To change the phase of G, you must act on the speed of the prime mover of G. lightly accelerating it***

When you check all the previous conditions for parallel operation and confirm it's all true then you can close the switch S1 as in figure #1



Figure# 1: A generator being paralleled with another generator.

Experiment Procedure :

1. Connect the circuit shown in the figure#2.

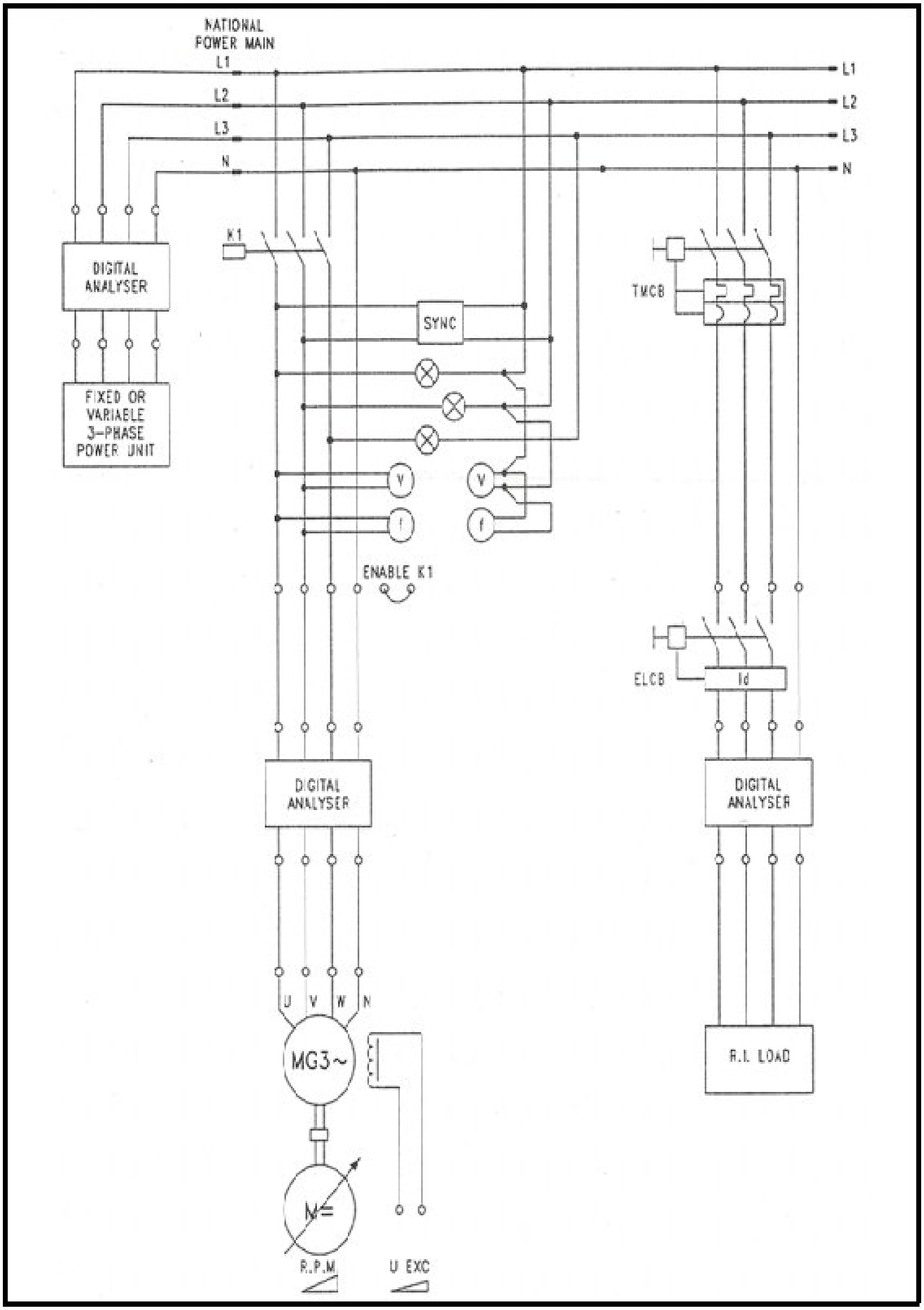

NATIONAL POWER MAIN
L1
L2
L3
N
L1
L2
L3
N
DIGITAL ANALYSER
FIXED OR VARIABLE 3-PHASE POWER UNIT
K1
SYNC
V
f
V
f
ENABLE K1
TMCB
ELCB
Id
DIGITAL ANALYSER
DIGITAL ANALYSER
U V W N
MG3~
M=
R.P.M.
U EXC
R.L. LOAD

Figure #2

2. Switch on the main supply and raise the voltage to obtain a terminal line to line voltage =400volt , with constant frequency=50Hz

3. Activate the prime mover of the synchronous generator and adjust its speed to obtain the output frequency (f=50) and increase the excitation current to get nominal line to line voltage (V=400 volt). **Note: don't enable the contactor K2 for any reason, in this phase.** **<u>At no load condition</u>** notice the synchronization devices (synchroscope and the three lamps) the ideal moment for carrying out the parallel connection of the synchronous generator G with the main supply Is the moment where the three lamps off and the Light of the synchroscope in the Green Zone. **<u>AT that moment press the green button of contactor K2</u>** to lead the generator to be connected in parallel with the main supply as shown in figure #3

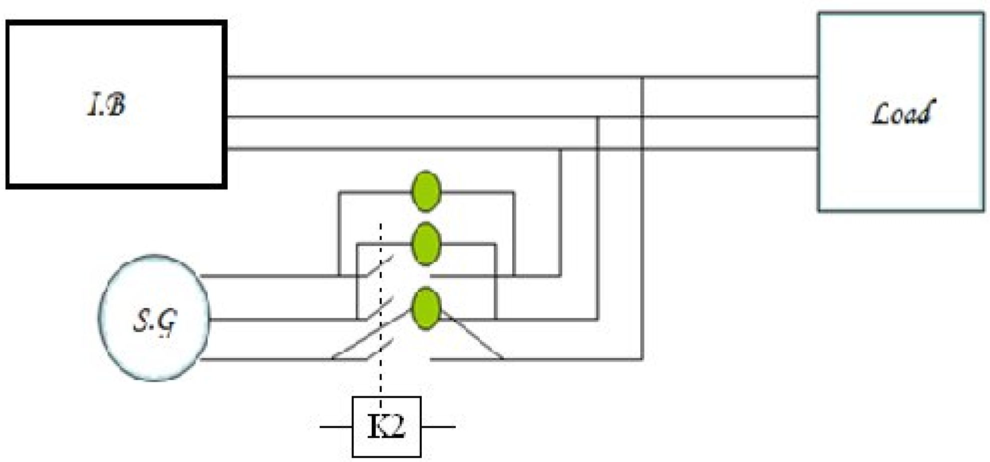


Figure #3: The three-light-bulb method for checking phase sequence.

<u>Part I: (A) The effect of changing frequency of the generator under load on real power sharing without inserting protection relays</u>

1. After making the synchronization of generator to be connected in parallel with the main supply successfully, add resistive inductive load and take the readings of the values in table #1

2. Vary the frequency of the synchronous generator G**(increase or decrease)** and fill the table

Select resistive load switch **A** inductive load switch **A**				
f_G (Hz)	**f_{sys} (Hz)**	**P_G (Watt)**	**$P_{main.supply}$ (Watt)**	**P_{load} (Watt)**
No changes				
Increasing f_G				
Decreasing f_G				

Table #1

Question#1:

What happens if the governor set point of the S.G is increased or decreased? Draw the house diagrams to explain the effect of changing the generator speed on the power sharing?

Part I: (B) The effect of changing excitation current of the generator under load on reactive power sharing without inserting protection relays:

1. Return back to the first values of frequency and terminal voltage at no load **.**

2. After making the synchronization of generator to be connected in parallel with the main supply successfully, add resistive inductive load and take the readings of the values in table #2

3. Vary the excitation current of the synchronous generator G**(increase or decrease)** and fill the table

<table>
<tr><td colspan="7">Select resistive load switch A inductive load switch A</td></tr>
<tr><td colspan="2">If generator
(Amp)</td><td>V_{sys}
(Volt)</td><td>Q_G
(VAR)</td><td>$Q_{main\ supply}$
(VAR)</td><td>Q_{load}
(VAR)</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Increasing
If</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">decreasing
If</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table #2

<u>Question#2:</u>

What happens if excitation current of the synchronous generator G is increased or decreased? Draw the house diagram to explain the effect of changing the excitation current of the synchronous generator reactive power sharing?

<u>Part II: (A) The effect of changing frequency of the generator under load on real power sharing with inserting protection relays</u>

1. Include all the protection relays and switch to automatic mode to get synchronization automatically when conditions are met for a synchronous generator parallel operation with the mains

2. Set the protection relays on the following settings**:**

- Sequence relay for phase lack and three-phase voltage asymmetry:
  - SYMMETRY = 10%;
  - Asymmetry intervention delay (DELAY) = 5 s.
- Max/min three-phase voltage relay:
  - Rated line voltage Ue = 400 V;
  - maximum voltage threshold (MAX VOLTAGE) = 105 %;
  - maximum voltage intervention delay (DELAY MAX) = 5 s;
  - minimum voltage threshold (MIN VOLTAGE) = 90 %;
  - minimum voltage intervention delay (DELAY MIN) = 5 s.
- MAX/min frequency relay:
  - rated mains frequency (FREQ.) = 50 Hz;
  - maximum frequency threshold (MAX) = 2 Hz;
  - maximum frequency intervention delay (DELAY MAX) = 5 s;
  - minimum frequency threshold (MIN) = 2 Hz;
  - minimum frequency intervention delay (DELAY MIN) = 5 s.
- Fixed-time three-phase ammetric relay for overload and short-circuit:
  - overload threshold = 1 A;
  - operation delay = 5 s;
  - short-circuit threshold = 5 A.

3. Repeat step 2 in **part I (A)** and tabulate your results in table #3

Select resistive load switch **A** inductive load switch **A**				
f_G (Hz)	**f_{sys} (Hz)**	**P_G (Watt)**	**$P_{main.supply}$ (Watt)**	**P_{load} (Watt)**
No changes				
Increasing f_G				
Decreasing f_G				

Table #3

Question#3:

What happens if the governor set point of the S.G is increased or decreased? Draw the house diagrams to explain the effect of changing the generator speed on the power sharing?

4. Repeat the steps 1,2 and 3 **in part I (B)** and tabulate your results in table #4

Select resistive load switch **A** inductive load switch **A**					
I_f generator (Amp)		**V_{sys} (Volt)**	**Q_G (VAR)**	**$Q_{main.supply}$ (VAR)**	**Q_{load} (VAR)**
Increasing **If**					
decreasing **If**					

Table #4

Question#4:

What happens if excitation current of the synchronous generator G is increased or decreased? Draw the house diagram to explain the effect of changing the excitation current of the synchronous generator reactive power sharing?

Write down your Conclusions

Experiment#9

Studying the operation of a power transmission line in condition of ground fault

Objectives:

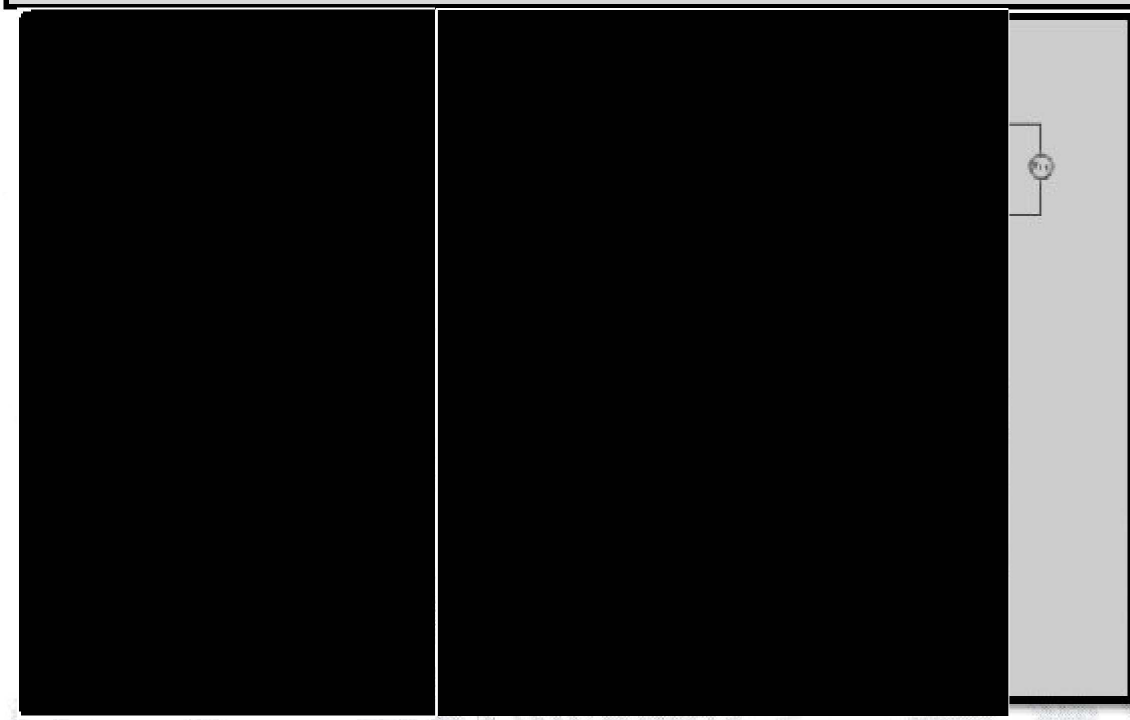
1. Studying the operation of power transmission line with neutral cable insulated in condition of ground fault.
2. Studying the operation of power transmission line with compensated neutral conductor (Peterson coil) in condition of ground fault.

Equipments required (Apparatuses):

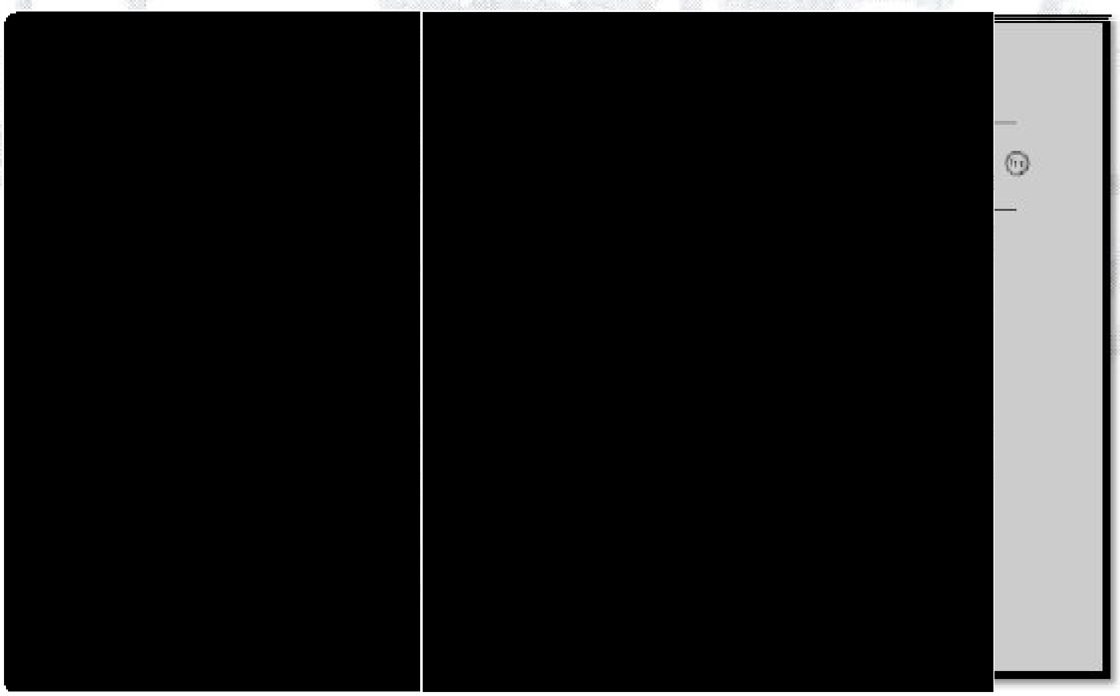
1. Similar of electric lines mod. SEL-1/EV.
2. Variable three phase power supply mod. AMT-3/EV, in option 3-phase line generated by the generator control board mod. GCB-1/EV, or a fixed 3-phase line 3X380v.
3. Three-phase transformer mod. P14A/EV.
4. Set of loads/jumpers for electrical connection.
5. 2 digital instruments for measuring the parameters of electric energy in 3-phase system mod. AZ-VIP (the instruments of the generator control board mod. GCB-1/EV can be used in option).
6. Variable resistive load mod. RL-2/EV or mod. RL-1/EV.
7. Variable inductive load mod. IL-2/EV.

Theory:

The single line ground fault current of an electric system insulated from ground, closes through the ground capacitance of the phases (it is defined CE), and consequently its value is not very high.
The ground fault current of the system with insulated neutral conductor (figure#1) will rise as the ground capacitance (CE) increases, that is as main is extended.
An alternative to the insulated neutral cable is represented by the grounding of this same cable through a coil (Peterson coil, or arc-suppression coil) as shown in (figure#2). The single phase ground fault current IF will result from the sum of the currents IL crossing the coil, and IC closing through the capacitance of the phases not suffering ground fault.



Figure# 1 Power transmission line with neutral cable insulated in condition of ground fault.

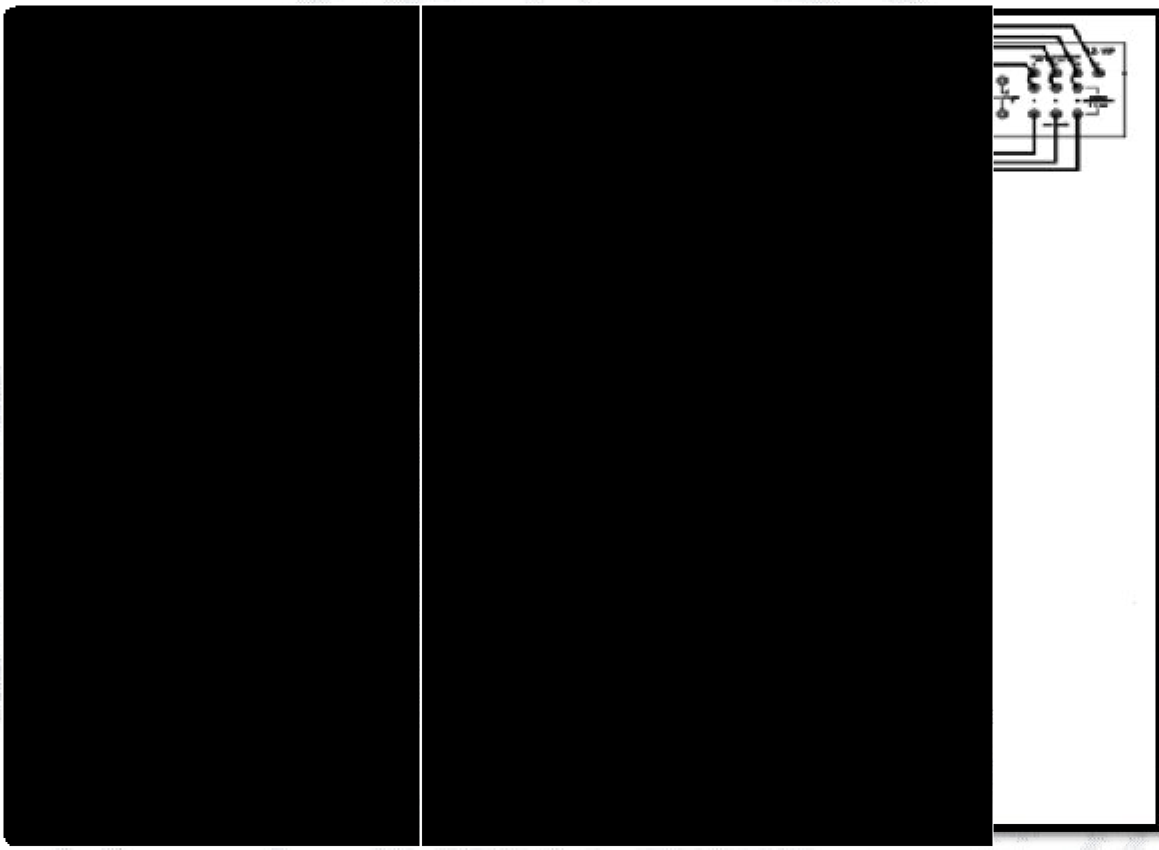


Figure#2 power transmission line with compensated neutral conductor in condition of ground fault.

Experimental procedure:

Part 1: Power transmission line with neutral cable insulated in condition of ground fault.

1. Connect the circuit as shown on the figure#3 which shows that there are no connection on the neutral line on this test



Figure#3 Power transmission line with neutral cable insulated in condition of ground fault.

2. Start this exercise considering the transmission LINE 2 with the following constants: Resistance = 18 Ω; Capacitance = 0.1µF; Inductance = 0.072 H; Length = 50 km; Section=50 mm2 - conductor of copper.
3. Turn the breakers at the origin and at the end of the LINE 2, to OFF.
4. Connect the measuring instruments between the left busway and the terminals at the starting of the LINE 2, and between the end terminals of the LINE 2 and the right busway.
5. Connect the jumpers of the both set of capacitors, in the LINE 2, to reproduce the capacitance between active conductors and ground equal 0.1uF (called CE).

6. Connect the left busway with the variable three-phase power supply. This exercise does not require any load in the right busway but here make a short circuit on the right busway between line1 and ground as shown in figure#3
7. Switch on the three – phase power supply and adjust the sending end voltage of the transmission line to 380volt and keep it constant throughout the test.
8. Turn the breaker at the origin and at the end of the Line 2 to ON
9. For instance, modify the set of capacitors C_E (via the proper selectors) and check the trend of ground fault current at sending end and reciving end and tabulate you results in table #1.

V_s (V)	CEs, CEr (µF)	C tot (µF)	I_{fs} (A)	I_{fr} (A)
380	0.1, 0.1	0.2		
380	0.1, 0.2	0.3		
380	0.2, 0.2	0.4		
380	0.1, 0.4	0.5		
380	0.2, 0.4	0.6		
380	0.4, 0.4	0.8		

Table #1

Question#1:

Explain is the effect of increasing the values of CEs &CEr on the fault current?

Question#2:

Plot the curve of C_{tot} versus I_{fr} and explain the effect of adding certain value of resistance in series with the faulted line?

Part 2: (A) Power transmission line with compensated neutral conductor in condition of Single phase to ground fault

1. Connect the circuit as shown in figure # 4 which shows that the neutral line is connected to the ground through variable inductor

Figure # 4 power transmission line with compensated neutral conductor in condition of ground fault.

2. Start this exercise considering the transmission LINE 2 with the following constants: Resistance = 18 Ω; Capacitance = 0.1μF; Inductance = 0.072 H; Length = 50 km; Section=50 mm2 - conductor of copper.
3. Turn the breakers at the origin and at the end of the LINE 2, to OFF.
4. Connect the measuring instruments between the left busway and the terminals at the starting of the LINE 2, and between the end terminals of the LINE 2 and the right busway.
5. Connect the jumpers of both set of capacitors, in the LINE 2, to reproduce the capacitance between active conductors and ground (called CE).

6. Connect the left busway with the variable three-phase power supply. This exercise does not require any load in the right busway but here make a short circuit on the right busway between **a phase of the line** and ground as shown in figure#3 **without any resistor connected in series with this fault line**.
7. Switch ion the three – phase power supply and adjust the sending end voltage of the transmission line to **380volt** and keep it constant throughout the test.
8. Turn the breaker at the origin and at the end of the Line 2 to ON
9. Select the values of **CEs = 0.2μF & CEr =0.2μF** and then vary the values of the inductor connected in series with the neutral line and measure the values of fault current at sending end and receiving end and tabulate your results in table #2.

V_s (V)	Inductance of compensation coil (L) (mH)		CEs, CEr (μF)	C tot (μF)	I_{fs} (A)	I_{fr} (A)
380	(C,C,C)	1.74	0.2, 0.2	0.4		
380	(B,C,C)	2.3	0.2, 0.2	0.4		
380	(A,C,C)	3.46	0.2, 0.2	0.4		
380	(A,B,C)	4.03	0.2, 0.2	0.4		
380	(A,A,C)	5.18	0.2, 0.2	0.4		
380	(A,A,B)	5.75	0.2, 0.2	0.4		
380	(A,A,A)	6.9	0.2, 0.2	0.4		

Table #2

10. Repeat the previous test in this part of experiment with a new values of CEs & CEr (select CEs = 0.4μF & CEr =0.4μF) and tabulate your results in table #3

V_s (V)	Inductance of compensation coil (L) (mH)		CEs, CEr (µF)	C tot (µF)	I_{fs} (A)	I_{fr} (A)
380	(C,C,C)	1.74	0.4, 0.4	0.8		
380	(B,C,C)	2.3	0.4, 0.4	0.8		
380	(A,C,C)	3.46	0.4, 0.4	0.8		
380	(A,B,C)	4.03	0.4, 0.4	0.8		
380	(A,A,C)	5.18	0.4, 0.4	0.8		
380	(A,A,B)	5.75	0.4, 0.4	0.8		
380	(A,A,A)	6.9	0.4, 0.4	0.8		

Table #3

Part 2: (B) Power transmission line with compensated neutral conductor in condition of Single phase to ground fault through 540 Ω resistor.

11. Connect a resistor =540Ω in series with the line to ground fault as shown in figure #5 and **repeat all steps in part 2 (A)** and tabulate your results in table #4 and table #5

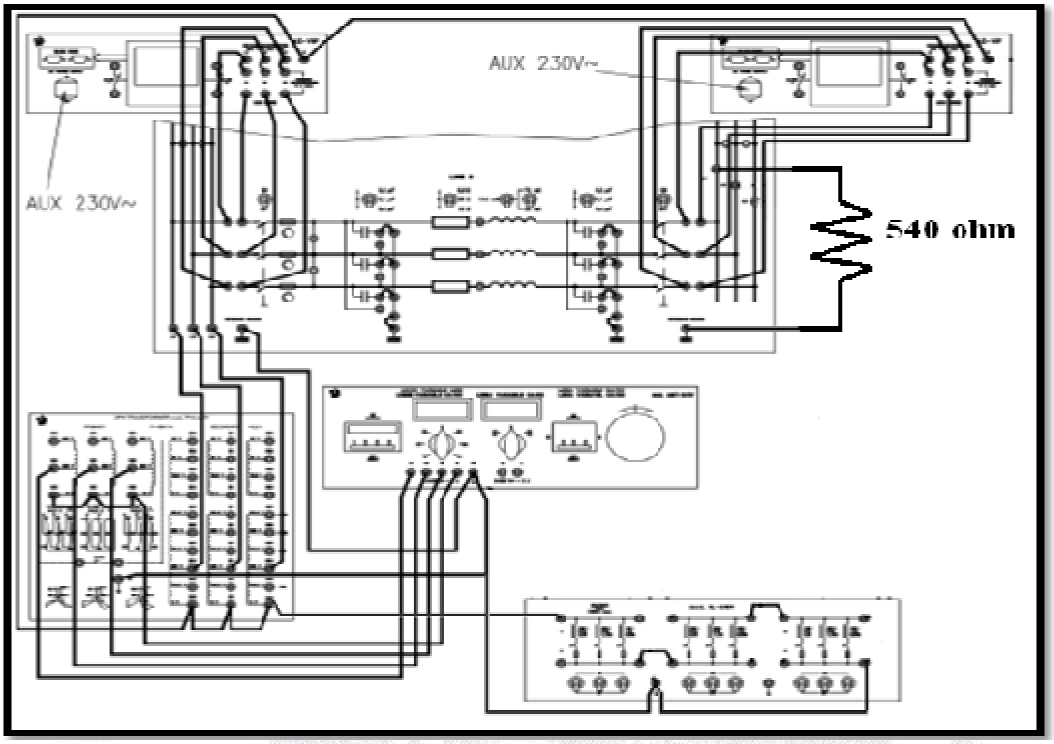


Table #4

V_s (V)	Inductance of compensation coil (L) (mH)		CEs, CEr (µF)	C tot (µF)	I_{fs} (A)	I_{fr} (A)
380	(C,C,C)	1.74	0.4, 0.4	0.8		
380	(B,C,C)	2.3	0.4, 0.4	0.8		
380	(A,C,C)	3.46	0.4, 0.4	0.8		
380	(A,B,C)	4.03	0.4, 0.4	0.8		
380	(A,A,C)	5.18	0.4, 0.4	0.8		
380	(A,A,B)	5.75	0.4, 0.4	0.8		
380	(A,A,A)	6.9	0.4, 0.4	0.8		

Table #5

Question#3:

Explain is the effect of increasing the values of the compensating inductor on the fault current?

Question#4:

Plot the curves of the receiving end fault current versus the inductance compensating inductor with deferent values of capacitors ?

Question#5:

Explain the effect of adding certain value of resistance in series with the fault line?

Write down your conclusions

Experiment #10
Power factor correction by using synchronous compensator

Objectives:

1. Carry out the connections and the sequence of operations to enable the synchronous compensator.
2. Detect the data of the system with a digital power analyzer

Theoretical notions.

Being in load or no-load condition, an under excited synchronous motor shows an Inductive load to the mains. On the contrary, when overexcited, it is equivalent to a capacitive load (function of synchronous compensator).

What is Synchronous Condenser?

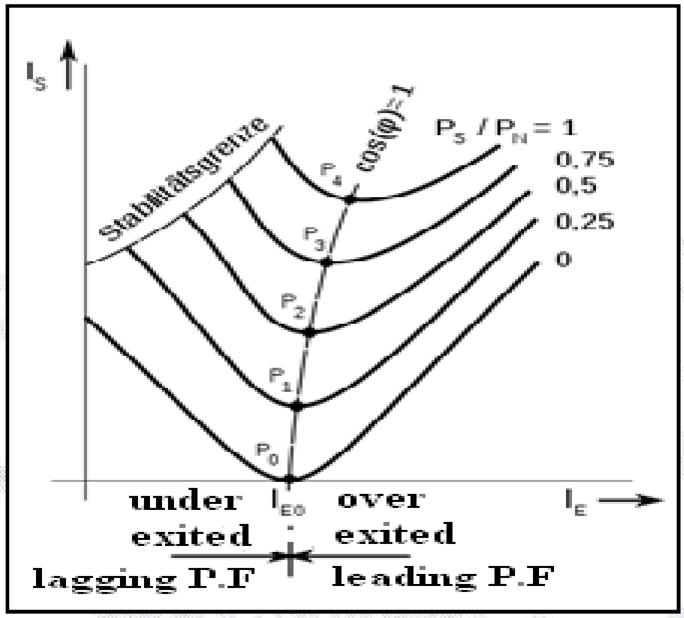
In electrical engineering, a synchronous condenser (sometimes synchronous capacitor or synchronous compensator) is a device identical to a synchronous motor, whose shaft is not connected to anything but spins freely.

Its purpose is not to convert electric power to mechanical power or vice versa, but to adjust conditions on the electric power transmission grid. Its field is controlled by a voltage regulator to either generate or absorb reactive power as needed to adjust the grid's voltage, or to improve power factor. The condenser's installation and operation are identical to large electric motors.

How does it work ?

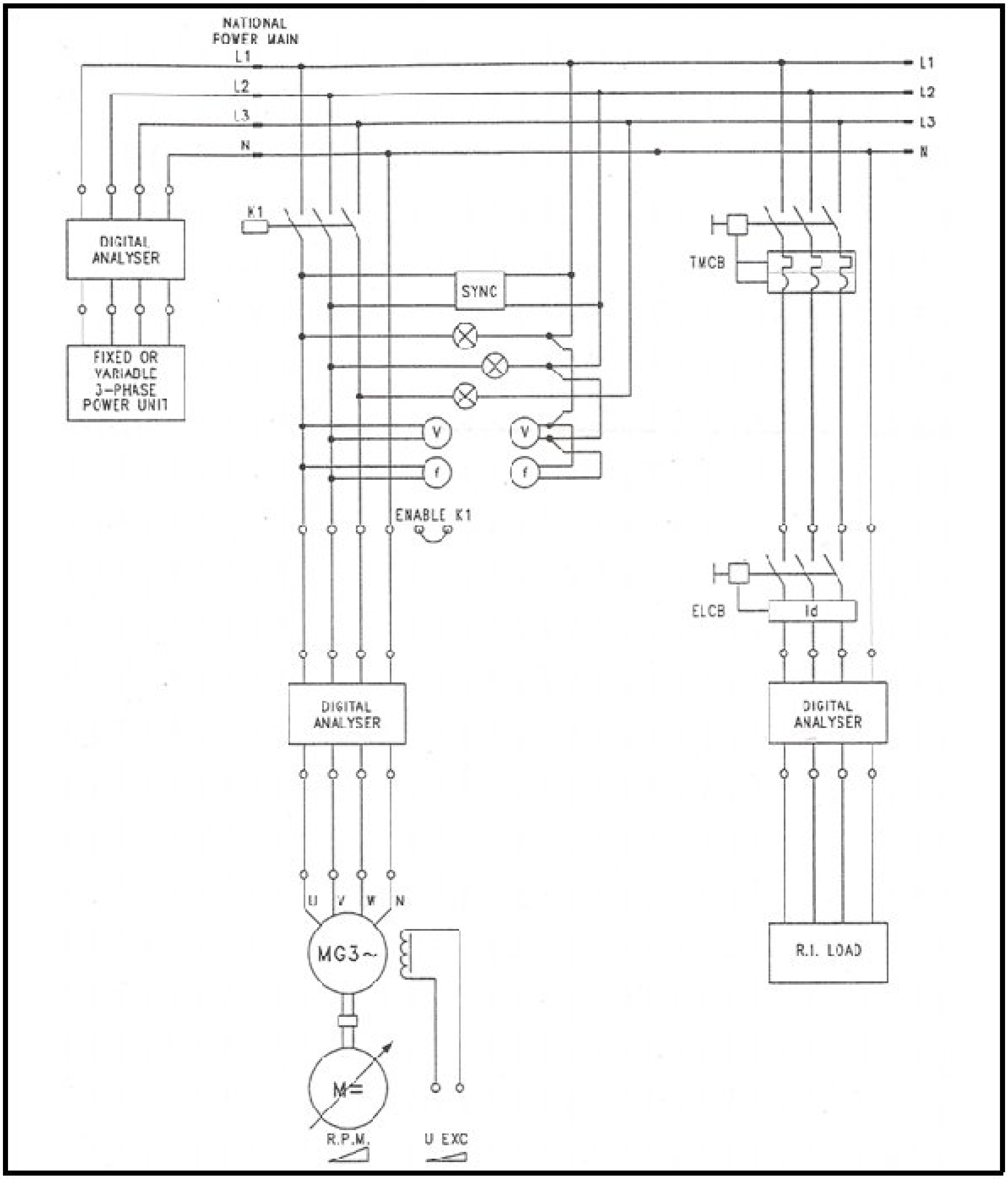
The following V curves **figure# 1** for a synchronous machine, shows a synchronous condenser operates at nearly zero real power. As the machine passes from under excited to overexcited, its stator current passes through a minimum.

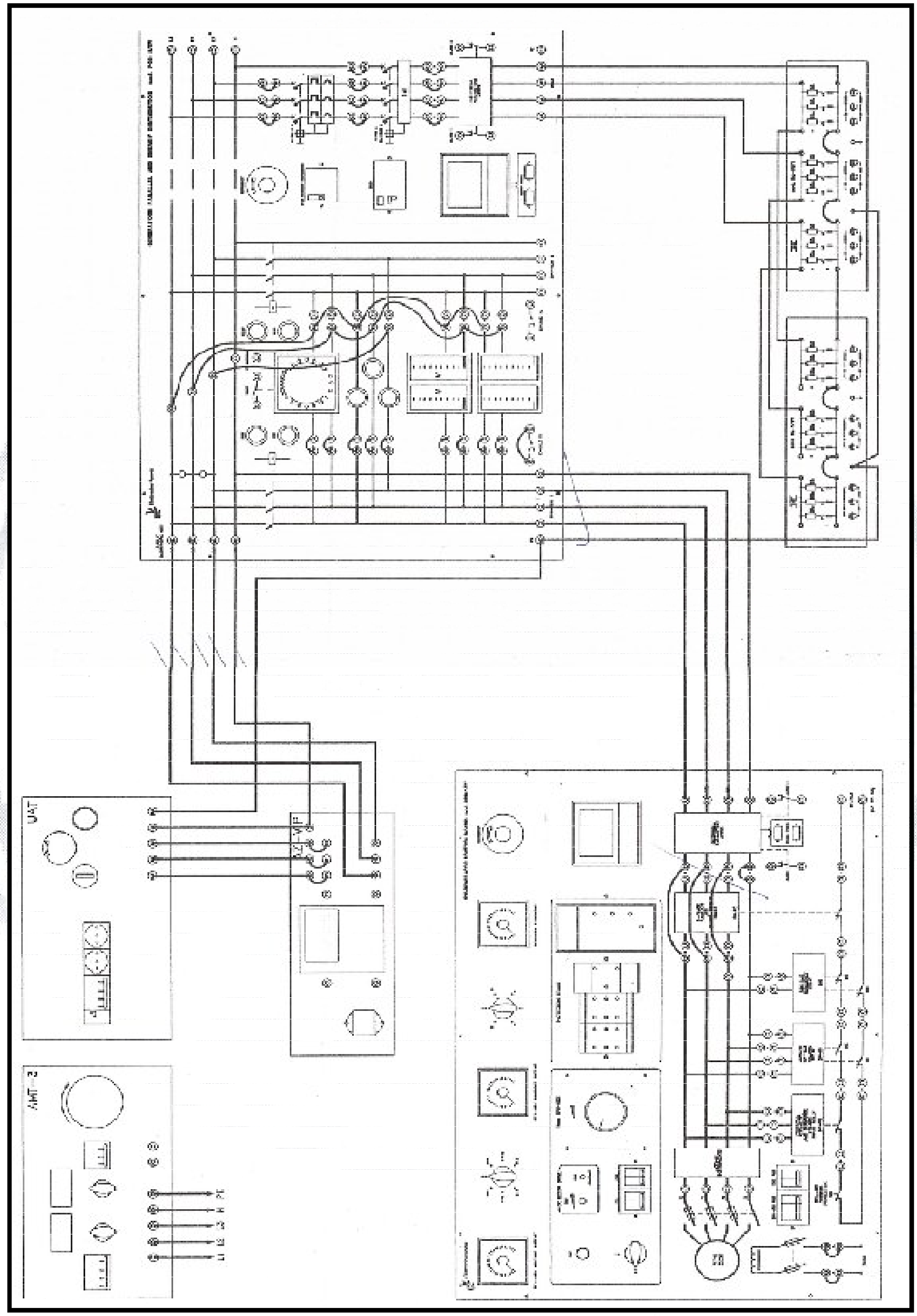
For the same output load, the armature current varies over a wide range and so causes the power factor also to vary accordingly. When over-excited, the motor runs with leading power factor and with lagging power factor when under-excited. In between, the power factor is unity. The minimum armature



9. Set of cables-jumpers for electrical connections.

Experiment procedure:





2. **At no load** start the prime mover of the control board for generating unit **(GCB-2/EV)**. And increase the speed and the excitation current to obtain the rated values of the synchronous generator **(the frequency =50Hz and terminal voltage = 400 volt**) like in the case of a parallel connection of a generator with the main supply.
3. Switch on the main supply and adjust its terminal voltage to 400 volt.
4. Carry out the proper adjustments to find the best "condition for the parallel connection" and carry it out. At this moment you have a three – phase generator connected in parallel with the main supply
5. **Still at no load** and without changing the excitation parameters of the synchronous compensator turn the switch **RUN/STAND-BY to STAND-BY**. Now this process transforms synchronous generator to become synchronous motor because the DC motor doesn't drive the synchronous generator any more**.**
6. **Still at no load** and try to adjust the excitation current of the synchronous motor to get a **power factor = 1** for that motor and the main supply and measure the values of real power line current and reactive power of the main supply and the synchronous motor. **($PF_{sys} = PF_{motor} = 1$ and $Q_{sys} = Q_{motor} = 0$)**
7. Now add a resistive - inductive load **(resistive load with switch B and inductive load with switch B)** ,**increase** the value of field current of the synchronous motor in steps to get the **power factor of the system= 0.94 lagging** and record the following measurements and the measurement in **table # 1**

P_{load}= Q_{load}= I_{load} = PF_{load}=

resistive switch AB and inductive switch AB								
IF (Amp)	System measurements				Motor measurements			
	P(Watt)	Q(VAR)	P.F	I(Amp)	P(Watt)	Q(VAR)	P.F	I(Amp)

Table # 1

8. Return back to the first readings at no load by adjusting the field current that is **PF_{sys}=PF_{motor}= 1 and Q_{sys}=Q_{motor}= 0.**
9. Now add a resistive - inductive load **(resistive load with switch B and inductive load with switch B)** ,**decrease** the value of field current of the synchronous motor in steps to and record the following measurements in table # 2

P_{load}= Q_{load}= I_{load} = PF_{load}=

resistive load with switch B and inductive load with switch B								
IF (Amp)	System measurements				Motor measurements			
	P(Watt)	Q(VAR)	P.F	I(Amp)	P(Watt)	Q(VAR)	P.F	I(Amp)

Table # 2

10. Repeat steps 6 ,7,8 & 6 for another resistive – inductive load **(resistive load with switch AB and inductive load with switch AB)**

Increasing IF

Pload= **Q**load= **I**load = **PF**load=

resistive switch AB and inductive switch AB								
IF (Amp)	System measurements				Motor measurements			
	P(Watt)	Q(VAR)	P.F	I(Amp)	P(Watt)	Q(VAR)	P.F	I(Amp)

Table # 3

Decreasing IF

Pload= **Q**load= **I**load = **PF**load=

resistive switch AB and inductive switch AB								
IF (Amp)	System measurements				Motor measurements			
	P(Watt)	Q(VAR)	P.F	I(Amp)	P(Watt)	Q(VAR)	P.F	I(Amp)

Table # 4

Question #1

What happen to the system power factor and the synchronous compensator when the field current is increased? Why?

Question #2

What happen to the system power factor and the synchronous compensator when the field current is decreased? Why?

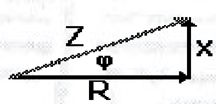
Write down your conclusions

Experiment # 11

$P_{avg} = VI \cos \varphi$

φ

$\text{POWER FACTOR} = \cos\varphi = \frac{R}{Z}$



in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current.

Utilities typically charge additional costs to customers who have a power factor below some limit, which is typically 0.9 to 0.95. Engineers are often interested in the power factor of a load as one of the factors that affect the efficiency of power transmission.

And low P.F implies:

1) Low P.F → large KVA Rating → Equivalent circuit for Device large and price will increase too.
2) Low P.F → High Currents (currents is α ——)→ High conductor size.

$$= \frac{}{\sqrt{}\times} = \frac{\overline{\quad}}{\sqrt{}\times}$$

and after improvement Q =Ql –Qc

$$= \frac{}{\sqrt{}\times} = \frac{\overline{(\quad)}}{\sqrt{}\times}$$ → I will decrease.

3) Low P.F→High currents→High Losses→ Low efficiency→ reduce Receiving end voltage.
4) Reduce handing capacity of system

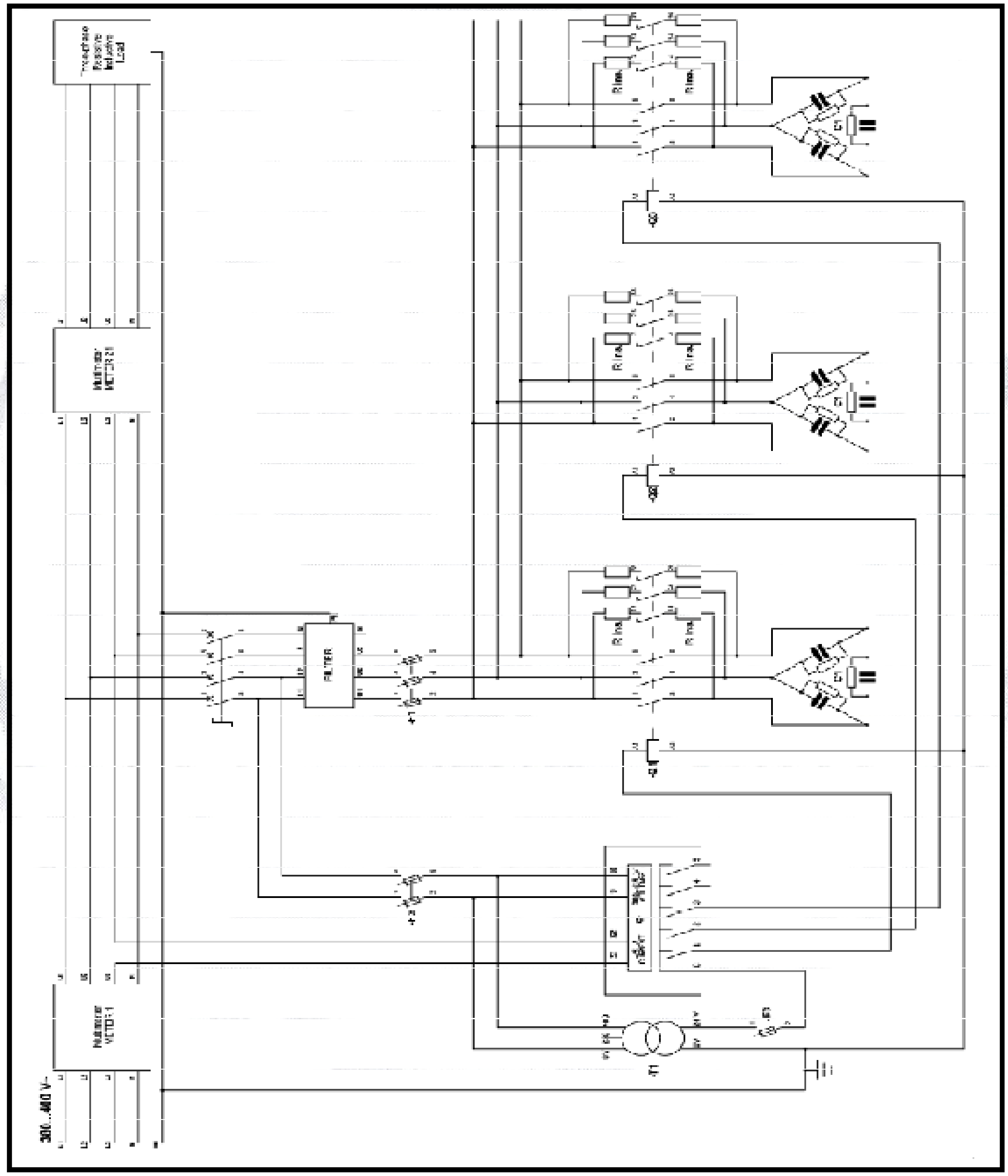
Power Factor correction methods.

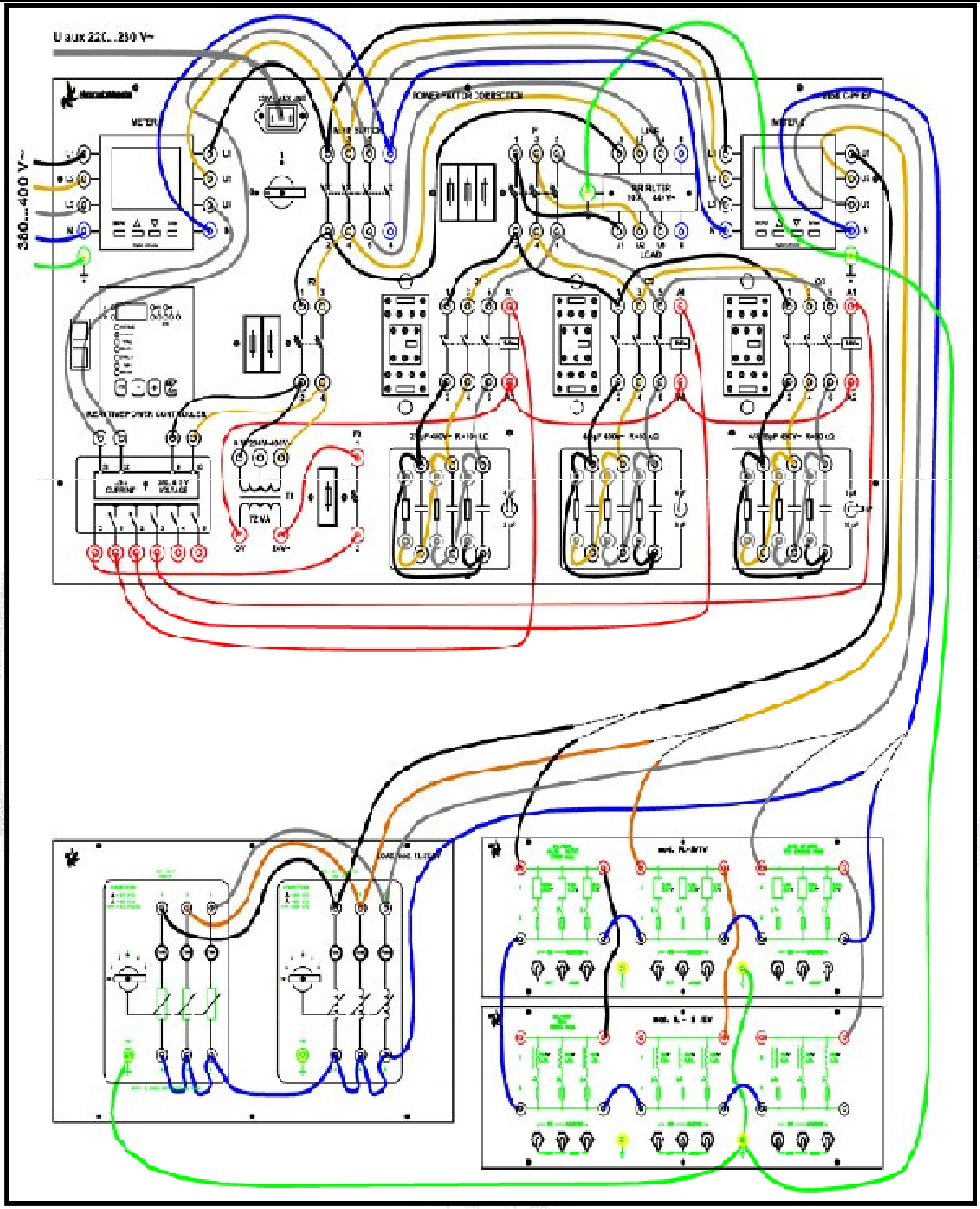
1) By using Capacitors Banks
2) By using Synchronous Condensers
3) By using Phase advancers

Equipments required (Apparatuses):

1. Variable 3-phase power supply mod. AMT-3/EV or constant three phase power supply UAT /EV.
2. Automatic Power Factor Correction System using capacitor Banks C – PF/EV
3. Variable resistive inductive load mod.RL-2k/EV.
4. Variable inductive load mod.IL-2/EV.
5. Set of jumpers and cables for electrical connection.

Experiment Procedure:




U aux 220...250 V~
380...400 V~

Part I A: manual mode of power factor correction with three deferent values of capacitors (C1=4µF, C2=8µF, C3=16µF)

3. Set the controller of the unit C – PF/EV on the manual mod by long press on the **auto /Manu** push Button.
4. Set the basic settings of this controller **P6 step 1=1, P6step 2=2, P6step 3=4** by pressing a long press on the **mode** push Button **and use the auto /Manu** push Button to reach to the function P6**.**
5. Set the advanced settings of this controller **P16** to the standard mod. by pressing a long press on the **mode** push Button and then long press on the **+ & -** together to inter to the advance settings **and use the auto /Manu** push Button to reach to the **function P16.**
6. **Set the desired power factor on the controller =0.94 lagging.**
7. Now start your test by adding various steps of resistive inductive loads and make the correction of the power factor using the manual mode by inserting the capacitors you need in parallel to the load and check the suitable value of these capacitors that mach the power factor of the system equal or near to the desired power factor and tabulate your results in table #1

R-L load	**R is set to step 2** **L1 is set to step 5** **L2 set to steps A B**	**R is set to step 2** **L1 is set to step 5** **L2 set to steps A B C** **L3 set to step B**	**R is set to step 1** **L1 is set to step 5** **L2 set to steps A B C** **L3 set to step A B C**
C1=4µF			
C2=8µF			
C3=16µF			
PF_{old}			
PF_{new}			
P_{in} total (watt)			
Q2=Qold = (Qload) (VAR)			
Q1=Qnew (VAR)			
I1 (Amp)			
I2 = ILoad (Amp)			

Table #1

Question#1

Calculate the required values of capacitance for each load by using **Qold and Qnew** and compare it to the values selected by the device.

Part I B: Automatic mode of power factor correction with three deferent values of capacitors (C1=4µF, C2=8µF, C3=16µF)

1. Switch off the power supply and C – PF/EV unit and return back to the no load case with the same connection.
2. Restart the system again and turn the mode to the automatic mode by pressing a long press on the **auto /Manu** push Button and start to vary the resistive inductive load in steps and let the controller of the system correct the power factor automatically and tabulate your results in table #2

R-L load	R is set to step 2 L1 is set to step 5 L2 set to steps A B	R is set to step 2 L1 is set to step 5 L2 set to steps A B C L3 set to step B	R is set to step 1 L1 is set to step 5 L2 set to steps A B C L3 set to step A B C
C1=4µF			
C2=8µF			
C3=16µF			
PF_{old}			
PF_{new}			
P_{in} total (watt)			
Q2=Qold = (Qload) (VAR)			
Q1=Qnew (VAR)			
I1 (Amp)			
I2 = ILoad (Amp)			

Table #2

Question#2

Calculate the required values of capacitance for each load by using **Qold and Qnew** and compare it to the values selected by the device ?

Question#3

Make a comparison between your results in of manual mode with the results of the automatic mode. What do you notice about that?

Part II A: Manual mode of power factor correction with three equal capacitors (C1=4µF, C2=4µF, C3=4µF)

1. Switch off the power supply and C – PF/EV unit and return back to the no load case with the same connection.
2. Restart the system again and turn the mod. to the manual mode. by pressing long press on the **auto /Manu** push Button .
3. Set the basic settings of this controller **P6 step 1=1, P6step 2=1, P6step 3=1** by pressing a long press on the **mode** push Button **and use the auto /Manu** push Button to reach to the function P6**.**
4. Set the advanced settings of this controller **P16** to the linear mod. by pressing a long press on the **mode** push Button and then long press on the **+ & -** together to inter to the advance settings **and use the auto /Manu** push Button to reach to the **function P16.**
5. **Set the desired power factor on the controller =0.94 lagging.**
6. Now start your test by adding various steps of resistive inductive loads and make the correction of the power factor using the manual mod by inserting the capacitor you need parallel to the load and check the suitable value of these capacitors that mach the power factor of the system equal or near to the desired power factor and tabulate your results in table #3.

R-L load	R is set to step 2 L1 is set to step 3	R is set to step 2 L1 is set to step 5 L2 set to steps B	R is set to step 2 L1 is set to step 5 L2 set to steps A C
C1=4µF			
C2=4µF			
C3=4µF			
PF_{old}			
PF_{new}			
P_{in} total (watt)			
Q2=Qold= (Qload) (VAR)			
Q1=Qnew (VAR)			
I1 (Amp)			
I2=ILoad (Amp)			

Table #3

Question#4

Calculate the required values of capacitance for each load by using **Qold and Qnew** and compare it to the values selected by the device ?

Part II B: Automatic mode of power factor correction with three equal capacitors (C1=4µF, C2=4µF, C3=4µF)

1. **Switch off** the power supply and **C – PF/EV** unit and return back to the no load case with the same connection.
2. Restart the system again and turn the mod. to the **automatic** mod. by pressing long press on the **auto /Manu** push Button and start to vary the resistive inductive load in steps and let the controller of the system correct the power factor automatically and tabulate your results in table #4

R-L load	R is set to step 2 L1 is set to step 3	R is set to step 2 L1 is set to step 5 L2 set to steps B	R is set to step 2 L1 is set to step 5 L2 set to steps A C
C1=4µF			
C2=4µF			
C3=4µF			
PF_{old}			
PF_{new}			
P_{in} total (watt)			
Q2=Qold = (Qload) (VAR)			
Q1=Qnew (VAR)			
I1 (Amp)			
I2 = ILoad (Amp)			

Table #4

Question#5

Calculate the required values of capacitance for each load by using **Qold and Qnew** and compare it to the values selected by the device ?

Question#6

Make a comparison between your results in of manual mode with the results of the automatic mode. What do you notice about that?

Write down your conclusions.

Experiment # 12

Study the operation of protection relays including distance protection relays on a power system

Objectives

The present exercise is dedicated to:

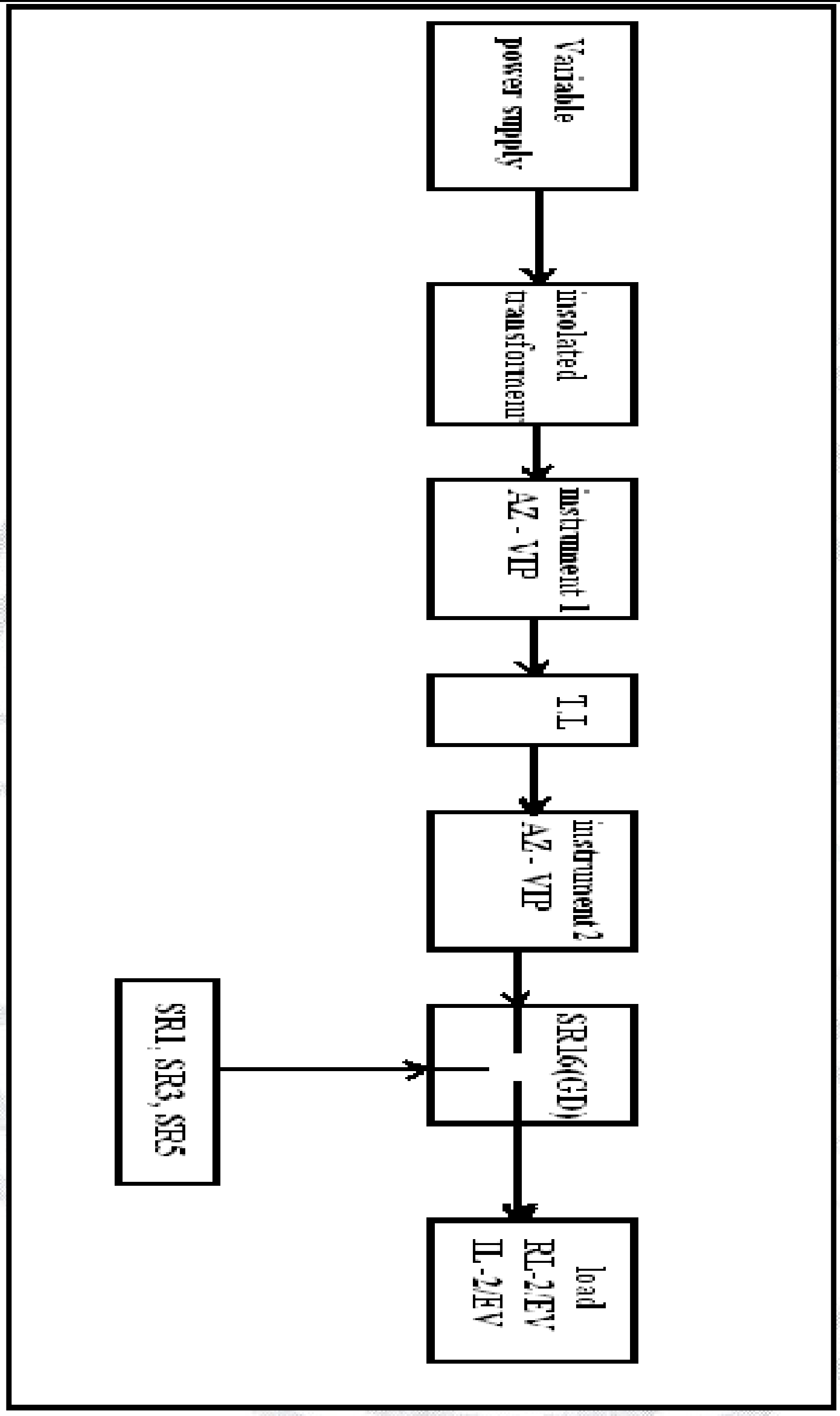
1. Connect the distance relay SR-16 with all its accessories (SR20 + SR21).
2. To test the relay action with a phase-to-ground failure in an HV line.
3. To test the relay action with a phase-to-failure in an HV line.
4. Study the operation of protection relays with a system consisting of a power supply, a transmission line and load.

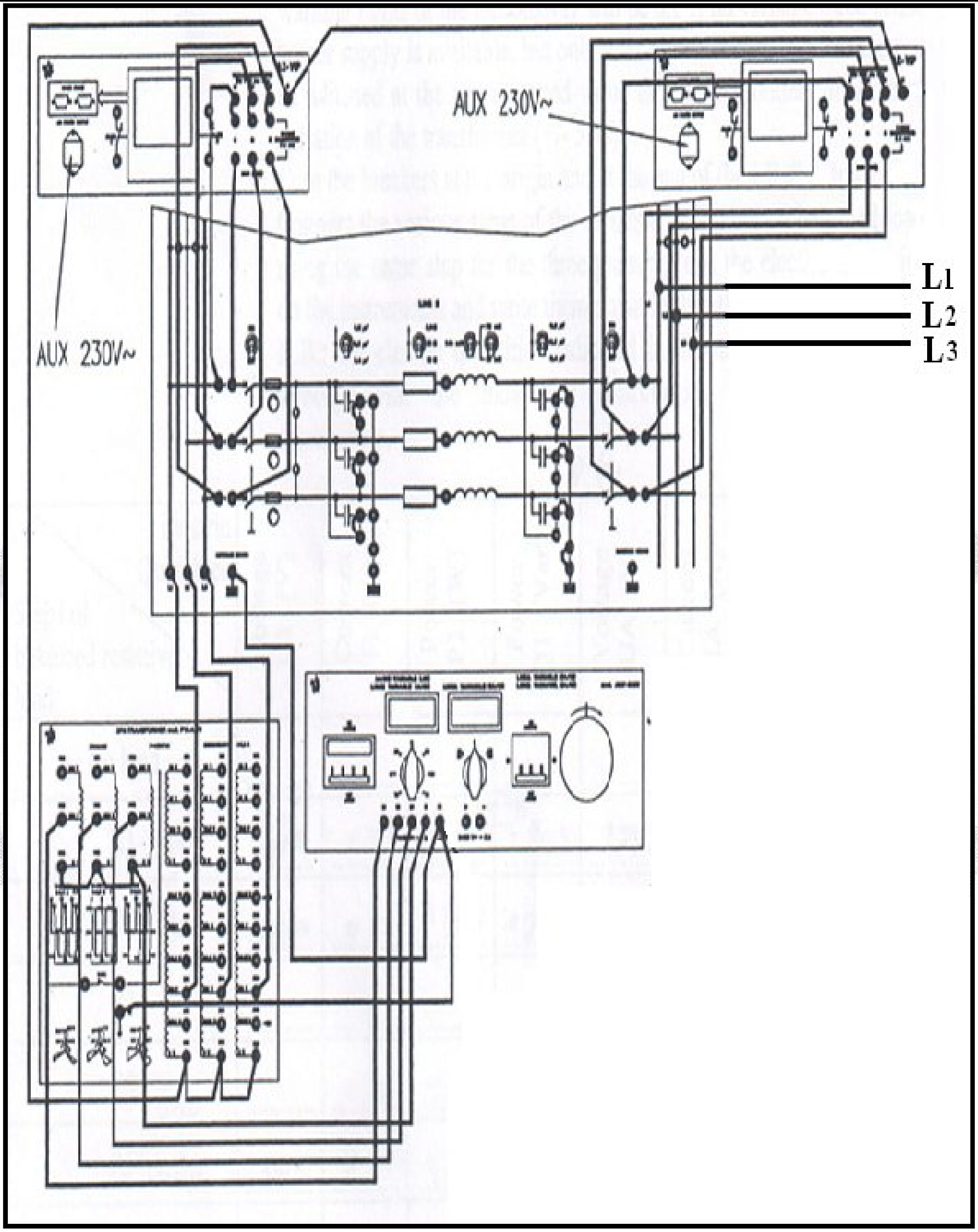
Equipments required (Apparatuses):

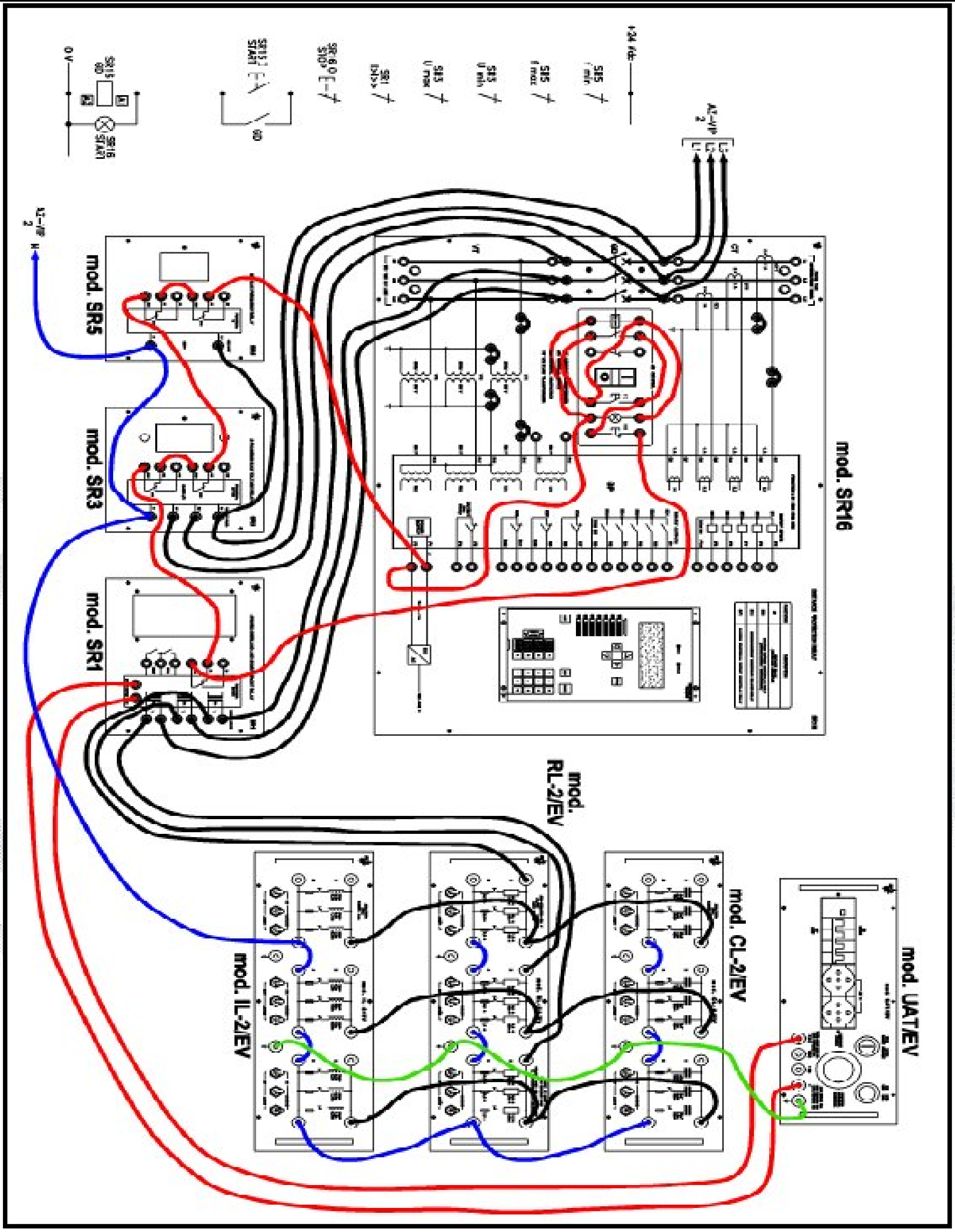
1. Variable Power Supply AMT-3/EV.
2. Isolated Transformer P-14/EV.
3. Transmission Line Simulator SEL-1/EV.
4. Digital Power Analyzer AZ-VIP
5. Module SR16/EV Distance Protection Relay Panel. The Panel should be connected to a PC via the RS232 cable.
6. Module SR20/EV HV Line Simulator.
7. Module SR21/EV Isolation transformer.
8. Protection Relay (over current relay) SR1/EV.
9. Protection Relay (max/ min voltage relay) SR3/EV.
10. Protection Relay (max/ min frequency relay) SR5/EV.
11. Power Supply UAT/EV.
12. Resistive Load RL-2/EV.
13. Inductive Load IL-2/EV.

Experiment Procedure:

4. Connect the circuit shown in the figure#1- A , figure#1- B and figure#1- C .


Variable power supply
insolated transformeur
instrument 1 AZ - VIP
T.L
instrument 2 AZ - VIP
SR16(GD)
load RL-2/EV IL-2/EV
SR1, SR3, SR5


AUX 230V~
AUX 230V~
L1
L2
L3


mod. SR5
mod. SR3
mod. SR1
mod. SR16
mod. RL-2/EV
mod. CL-2/EV
mod. IL-2/EV
mod. UAT/EV

5. At no load Switch on the power supply and start the control circuit of the protection relays **SR1 (over current relay) , SR3 (max/ min voltage relay) and SR5 (max/ min frequency relay)** then adjust the protection relays to certain different tripping values of current, voltage, frequency and time .
6. The relay you want to test must has smaller values of tripping time than the others
7. Now start to add different values of resistive - inductive load in steps and check the tripping of the over current relays by regulating the terminal voltage to 400 volt in each step and tabulate your results in table #1

Over current relay settings SR1(Over load current=1 Amp & time delay =5 sec)

Terminal Voltage (V)	Load Current (Amp)	Time of tripping (sec)

Table #1

8. Return back to the no load case and terminal voltage = 400 volt and readjust the protection relays (increase the time of tripping of over current relay and decrease it for **SR3 (over / under voltage relay)** to check the over / under voltage relay and then start to vary the resistive - inductive load in steps and check the tripping of the over / under voltage relay **<u>without regulating the terminal voltage</u>** and tabulate your results in table #2

Over/ under voltage relay settings (under voltage = -10% & time delay =5 sec)

Terminal Voltage (V)	Load Current (Amp)	Time of tripping (sec)

Table #2

9. With a certain resistive inductive load and at 400 volt terminal voltage try to increase the terminal voltage in steps and notice the value at which the over voltage relay trip and tabulate your results in table #3

Over/ under voltage relay settings (over voltage =+6% & time delay =5 sec)

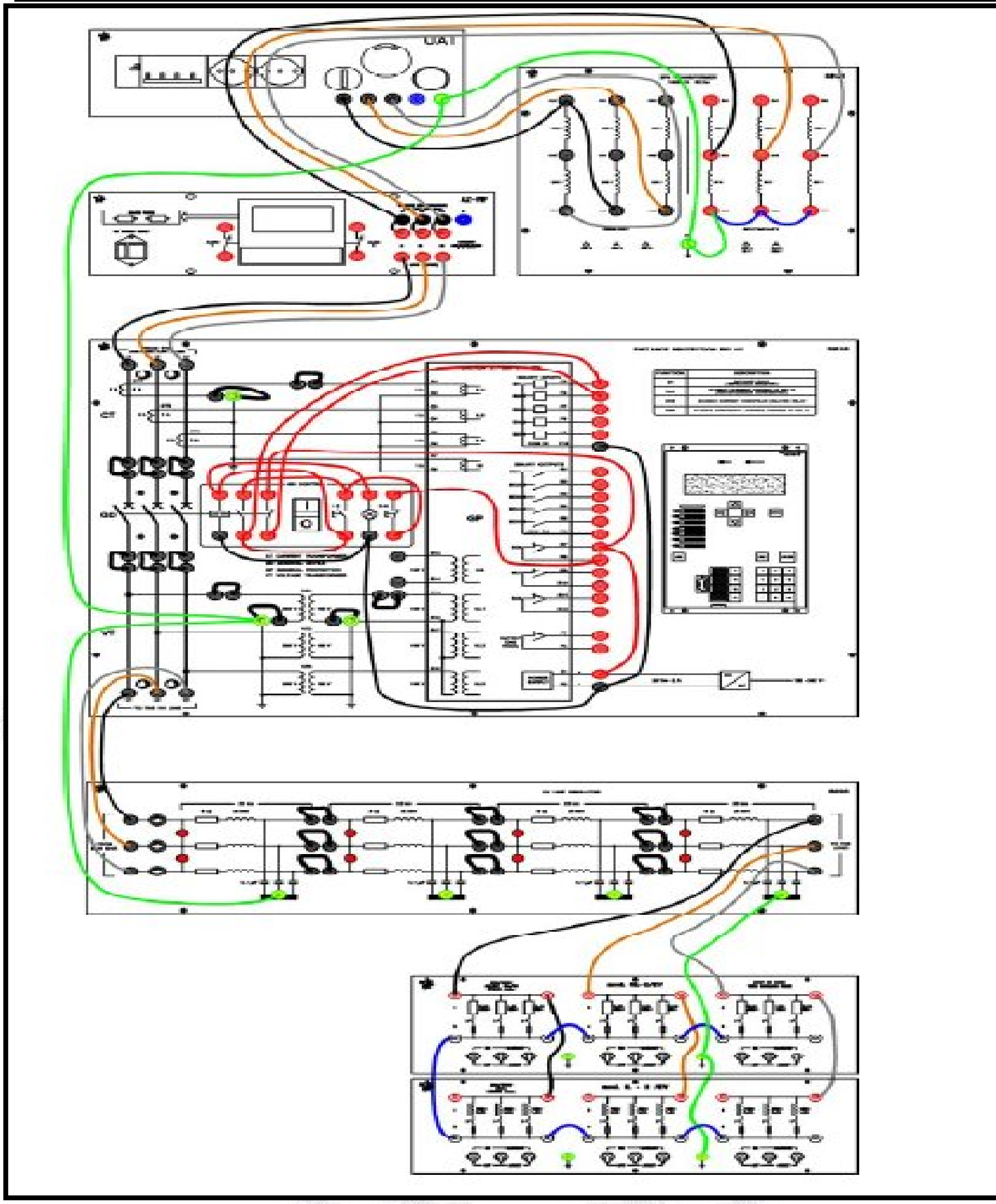
Terminal Voltage (V)	Load Current (Amp)	Time of tripping (sec)

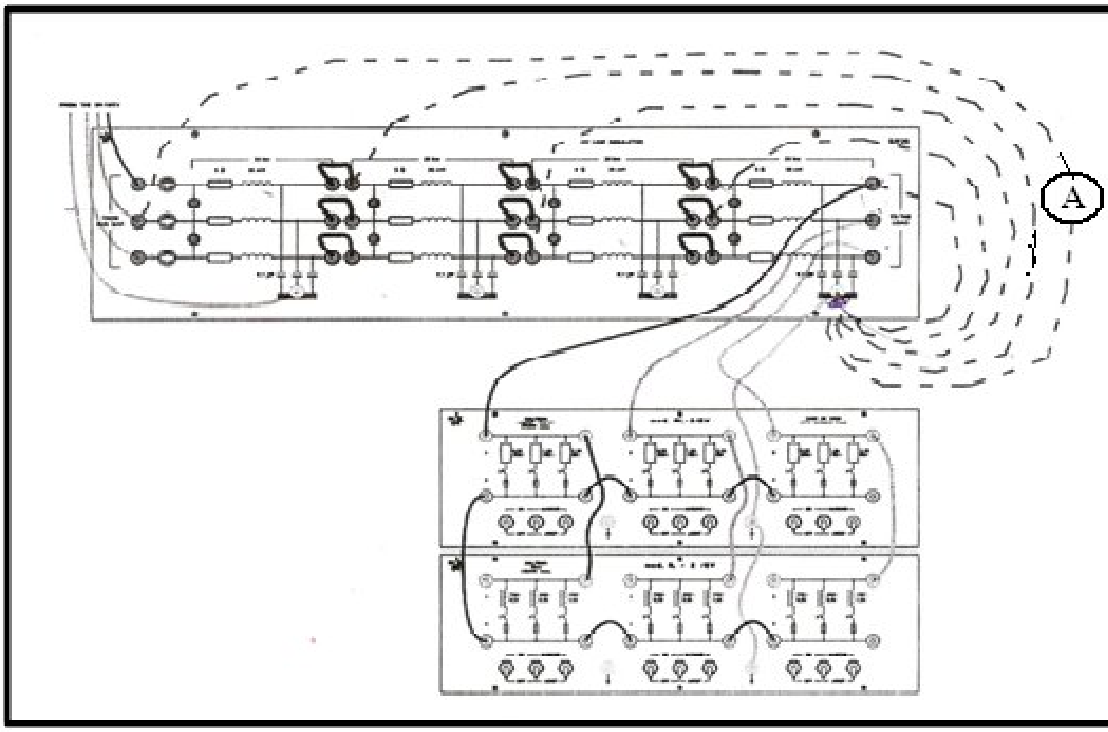
Table #3

Distances relay protection:

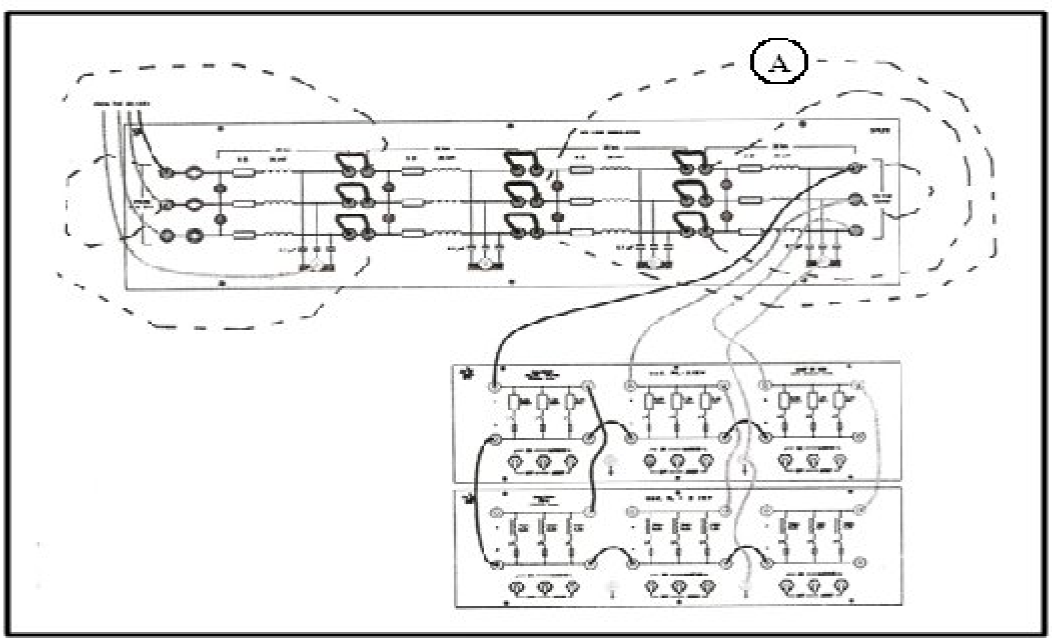
Part I : line to ground fault

1. Connect the circuit as shown in figure#2


UAT



Test.2: Phase to Ground Fault at Full Resistive Load (switches A,B,C)



Test.1: Phase to Phase Fault at No Load					
Test	**Distance (km)**	**Measured Distance (km)**	**Distance Error (%)**	**PU Time (ms)**	**I Fault (A)**
1	100				
2	75				
3	50				
4	25				

Table #6

5. Add all switches of resistive load and then repeat the line to line fault and tabulate your results in table #7

Test.2: Phase to Phase Fault at Full Resistive Load					
Test	**Distance (km)**	**Measured Distance (km)**	**Distance Error (%)**	**PU Time (ms)**	**I Fault (A)**
1	100				
2	75				
3	50				
4	25				

Table #7

Write down your conclusions

Experiment #13

The operation of an over all power system

Objectives :

1. Study the full operation of integrated power system starting from the generating units till the loads.
2. Study the different load conditions of the system.
3. Study the effects of capacitor installation on the voltages, reactive power and P.F.

Equipments :

1. Two motor-generator units mod.MSG-2/EV.
2. Two control panels for the M-G units ,mod. GCB-2/EV.
3. Parallel panel, mod. PCB-2/EV.
4. Three phase transformer, mod. P-14A/EV.
5. HV simulator mod.SEL-1/EV.
6. Multifunction instruments mod.AZ-VIP/EV.
7. Resistive load mod.RL-2A/EV.
8. Inductive load mod. IL-2/EV.
9. Capacitive load mod.CL-2/EV.

Preparing the experiment :

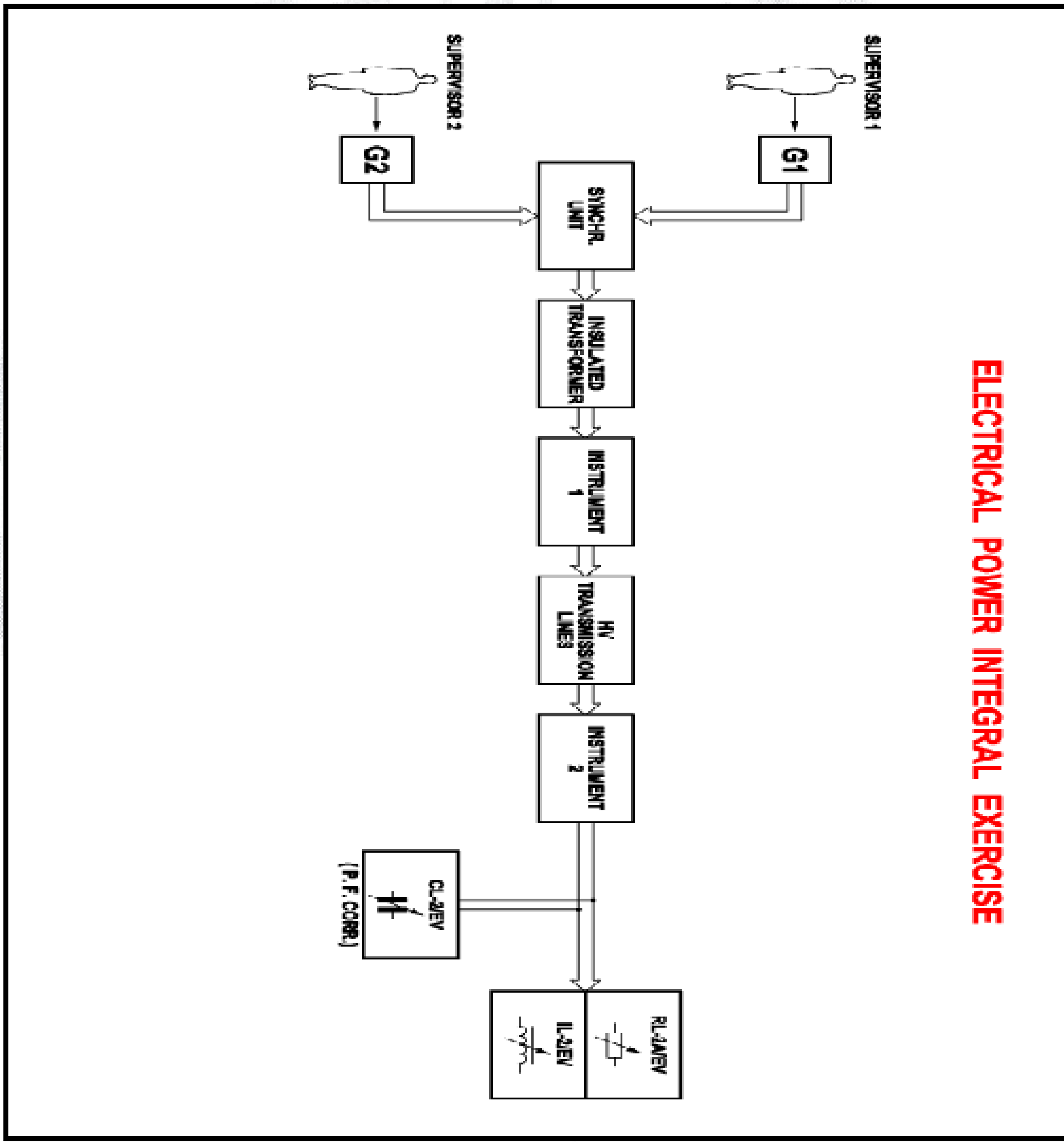
This experiment requires an integration between many stages as explained:

Stage I: The two motor-generator units must be synchronized and paralleled in the same procedure as did in previous experiments under suitable conditions.

Stage II : The output of the paralleled panel is connected to the primary of an insolated transformer (Star connection) , and the secondary of this transformer is connected star connection as well, make sure the ratio is 1 to 1 so that the transformer is used as an isolator.

Stage III: The secondary of the isolating transformer is connected to the HV simulator through multifunction instruments.

Stage IV: The output of the HV simulator is connected to (Star connected) R-L



Experimental procedure :

connect the circuit ac shown in **figure #2-A and figure #2-B**

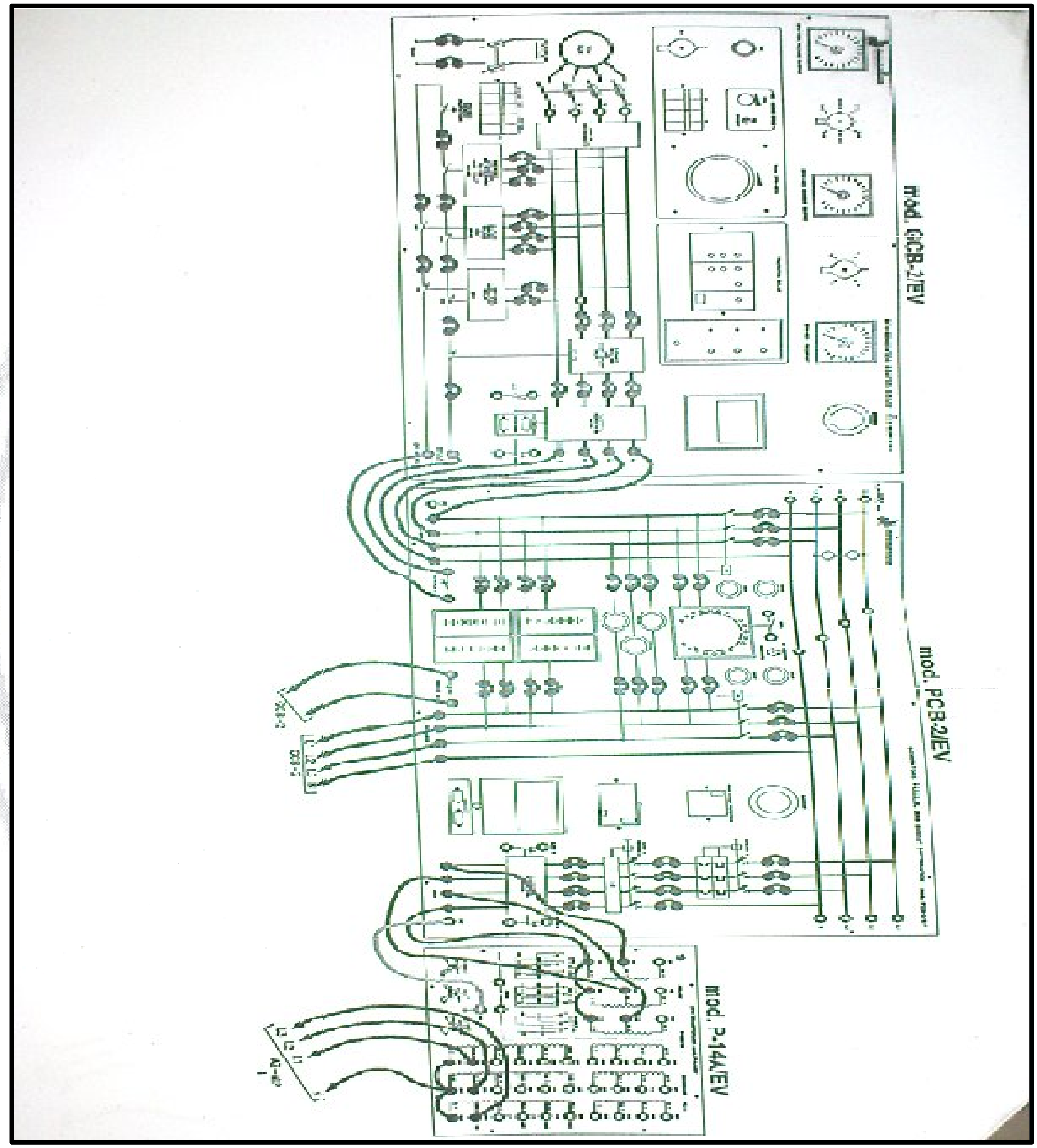


Figure #2-A

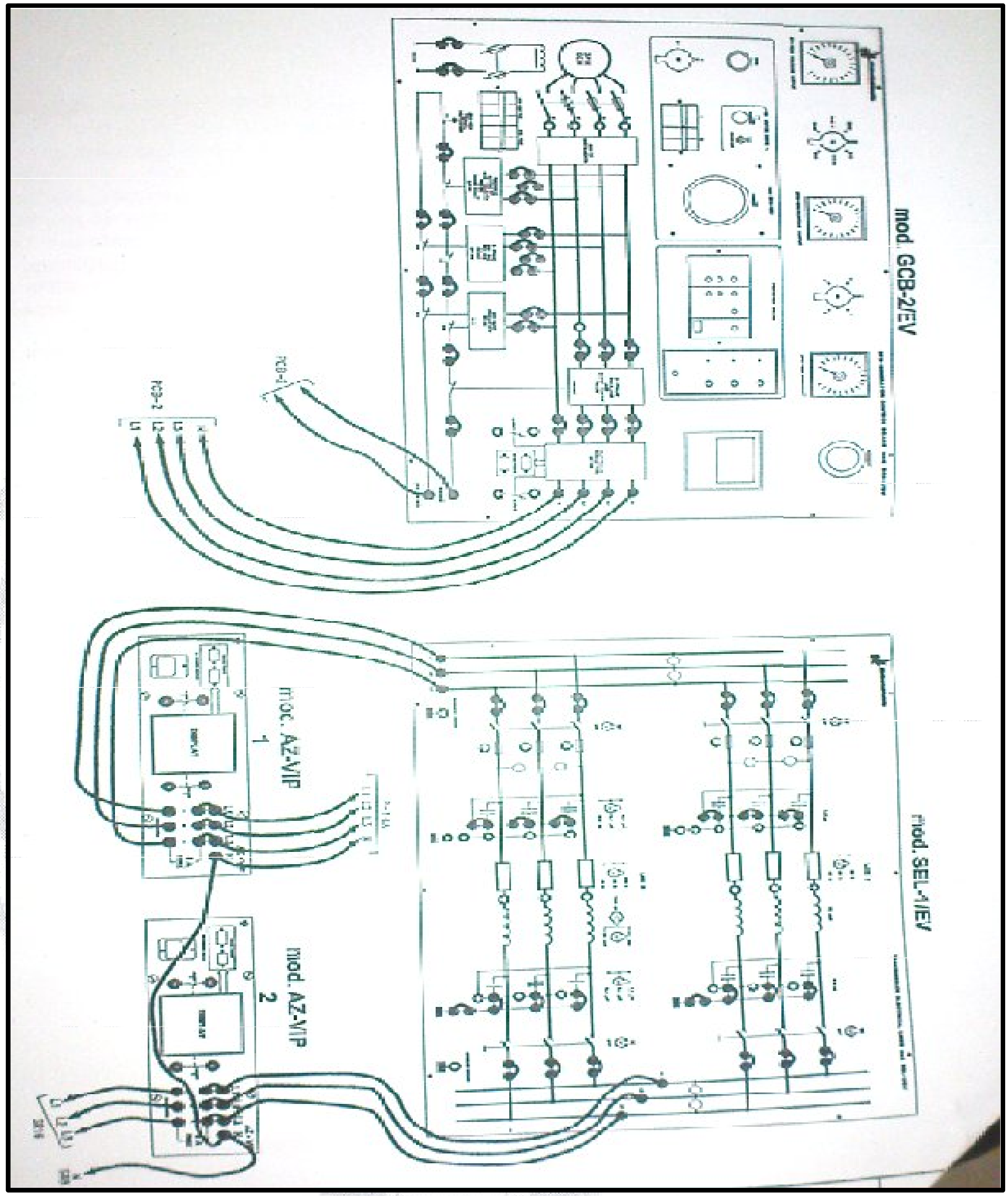


Figure #2-B

1. Figure #2- B shows that you must connect the two transmission line in parallel to be able to increase the value of the load current more than 1.5

amp. Set the parameters of both transmission lines as follow :**R= 18 Ohm , L = 72mH and C1 = C2 = 0.2 μF**.

2. Make the synchronization procedure of the two generators correctly after checking the synchronization condition as in previous experiments. That is **the line to line voltage of each of them is =380volt and the frequency is = 50 Hz**
3. Switch on the switches at the sending ends and receiving ends of the two transmission lines and vary the excitation current of the two generators to get **the line to line voltage at the sending ends of the two transmission line = 380volt**

Part I : No load test

1. Make sure that all loads are disconnected.
2. Adjust both generating units so that the terminal voltage of the power system remains unchanged **(380 volts).**
3. Cancel the capacitance effects from both lines by removing the jumpers totally.
4. Record your measurements for the values V_S ,V_R ,I_S ,$P.F_S$ and Q_S in table # 1
5. Repeat the same steps but connecting C1 & C2 for each T.L as: **I) ΔY, II)ΔΔ**

C1 connection	C2 connection	V_S (V)	V_R (V)	I_S (Amp)	$P.F_S$	Q_S (VAR)
OFF	OFF	380				
Δ	Y	380				
Δ	Δ	380				

Table # 1

Question #1

Explain your results for each case?

Part II : Load test (pure resistive load)

Very important note:

When adding any loads the terminal line to line voltage is varying in accordance to the load value so its vey important to keep it= 380 volt constant at the sending ends of the transmission lines by changing the excitation current of both generators .

1. Before connecting any load, make sure the terminal voltage is 380.
2. Connect the capacitors of both transmission lines **Δ connection** at the sending ends and **Y connection** at the receiving ends.
3. Insert various steps of the pure resistive load.
4. Users will have to maintain 380 volts at sending end of the transmission lines simulator by changing the excitation current of the two generators at the same time.
5. Record measurements and fill in the following table (table# 2).

R_{load} (Ω)	V_S (V)	V_R (V)	I_S (Amp)	I_R (Amp)	$P.F_S$	$P.F_R$	Q_S (VAR)
OFF	380						
A	380						
B	380						
AB	380						
C	380						
AC	380						
BC	380						
ABC	380						

(Table# 2)

Question#2

Draw and explain the following relationships:

1. **Q_S versus I_R**
2. **V_R versus I_R**

Part III : Load test and power factor correction (resistive – inductive load)

1. Before connecting any load, make sure that the terminal voltage at the sending ends of the transmission lines is **380 volt**.
2. Connect the capacitors of both transmission lines **Δ connection** at the sending ends and **Y connection** at the receiving ends.
3. Insert the first step of the pure resistive load **(switch A)** in parallel with an inductive load **(switches AB).**
4. Readjust the terminal voltage of the system to 380 volts by adjusting the excitation current of both generators.
5. Insert various steps of the pure capacitive load as a compensator to improve the P.F.
6. At each step you must maintain the terminal voltage at the sending ends of the transmission lines simulator **constant 380 volts** by changing the excitation current of the two generators at the same time.
7. Record measurements and fill in the following table (**table#3**).

resistive load (switch A) & inductive load (switches AB)							
C_{Load} (μF)	V_S (V)	V_R (V)	I_S (Amp)	I_R (Amp)	$P.F_S$	$P.F_R$	Q_S (VAR)
Off	380						
A	380						
B	380						
AB	380						
C	380						

(Table#3)

Question#3

Draw and explain the following relationships:

1. **Q_S versus C.**
2. **V_R versus C.**
3. **$P.F_R$ versus C.**

8. Repeat all steps of part III by adding a new resistive - inductive load resistive load **(switch A)** in parallel with an inductive load **(switches AC)**. Record your measurements and fill in the table **(table#4)**.

resistive load (switch A) & inductive load (switches AC)							
C_{Load} (µF)	**V_S (V)**	**V_R (V)**	**I_S (Amp)**	**I_R (Amp)**	**$P.F_S$**	**$P.F_R$**	**Q_S (VAR)**
Off	**380**						
A	**380**						
B	**380**						
AB	**380**						
C	**380**						

(Table#4).

<u>Question#4</u>

Draw and explain the following relationships::

1. **Q_S versus C.**
2. **V_R versus C.**
3. **$P.F_R$ versus C.**

<u>Question#5</u>

Compare the results you have in table #3 with the results you have in table #4? What do you notice about that?

System Stop

1. **Student 3 gradually unloads the system, while student 1 and 2 should be ready to modify accordingly the 2 M- GS parameters.**
2. **Disconnect first one of the M-G from the parallel. Be ready to modify accordingly the 2 M-GS parameters.**
3. **Disconnect the second M-G from the parallel**
4. **Perform the M-G stop procedure for both machines**

Writ e down your conclusions