REACTIVE POWER COMPENSATION USING 500KV, 180KM LINE TO MAINTAIN SUBSTANTIALLY FLAT VOLTAGE PROFILE AT ALL LEVELS OF AC TRANSMISSION SYSTEM

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Abstract: *The global economic recession has contributed in o small measure, in the increasing number of blackouts throughout the world as a result of voltage instability and collapse. The environmental consideration has also contributed by arresting the commission of new power stations and transmission lines, thus resulting in overload of the existing system. This calls for a change to a new direction by using the power system tool-box in MATLAB to stem down the tide. The results showed a balanced system, as confirmed by a substantial flat voltage profiles at all levels during transmission.*

Keywords: *Reactive Power, Compensation, Power System Tool-Box, Transmission Line, Voltage Collapse, Instability, Balanced System.*

1. INTRODUCTION

The function of power system is to provide every consumer, an electricity supply within tight bounds of frequency and voltage level while allowing them to switch appliances at will any time. The consumers also expect a reliable and secure supply of electricity even though they (consumers) are widely scattered and linked by extensive network of lines, cables and transformers which supply the electricity from distant power stations [1]. To meet these tasks, the power utility companies are faced with difficult technical problems coupled and complicated by financial constraints. Going memory lane, the turning points of these problems have been the 1973 – 4 oil crisis which besides leading to a dramatic increase of fuel prices had set off a world-wide economic recession that severely curtailed the growth of electricity demand [8]. The financial repercussions have severely constrained the electric utilities in their outlays on the power networks, at the very time when fuel costs radically altered generation patterns, leading to much higher loading on the interconnections within the transmission grid. Since this global economic recession, difficulties have emerged and worsened as environmental considerations have delayed or resisted the commissioning of new power stations and transmission lines [8].

All these factors have contributed to the changing modes of power system operation, where each utility had been self sufficient before but are now interdependent on neighbours because of heavy power interchanges. Although, there have been advances in the operational control of power system [4], these have not kept pace with the growing operational complexities. The results of these difficulties have been the increasing number of blackouts throughout the world, many due to system voltage instability. This calls for the need for a new direction in power system control to overcome the present technical difficulties as well as gaining economies for the power utilities. Reactive power compensation by employing the power system tool-box offers an opportunity to develop a new direction for power system control.

2.0 REACTIVE POWER COMPENSATION

Reactive power compensation can be defined as the management of reactive power to improve the ac power system performance. It is the supply of reactive power in a transmission system to increase the transmittable power, thereby making it compatible with the prevailing load demand. Therefore dynamic compensation is the reactive power compensation that is able to adjust its reactive power automatically so that the concerned system power factors are maintained within the desirable limits. The concepts of Volt Ampere Reactive (VAR) compensation embraces a wide and diverse field of both system and consumer problems, especially related with power quality issues since most of the power quality problems can be attenuated or solved with adequate control of reactive power [3]. The above topic tries to analyze the need for reactive power balance and voltage control in ac transmission lines with a view of contributing its own quota in solving one of the major problems and challenges in power system engineering. In general, the problem of reactive power compensation can be viewed from two perspectives (i) Load compensation and (ii) Voltage support. In load compensation, the objective is to increase the value of the system power factor to balance the real power drawn from the a.c. supply, compensate voltage regulation and eliminate current harmonic components produced by large and fluctuating nonlinear industrial loads [6]. Voltage support is generally required to reduce voltage fluctuation at a given terminal of a transmission line in order to balance the system.

Reactive power compensation in a transmission line improves the stability of a.c. system by increasing the maximum active power that can be transmitted. It also helps to maintain a substantially flat voltage profile at all levels of power transmission, increases transmission efficiency, controls steady-state and temporary over voltage [3], and can avoid disastrous blackouts [2].

3.0 VOLTAGE COLLAPSE OR VOLTAGE INSTABILITY

Voltage collapse or instability is the process by which instability leads to loss of voltage in the significant part of the system. Here voltage may be lost due to "angle stability as well. Voltage instability is of increasing importance to utility companies and instability and collapse incidents have been reported in the literature [6], for instance:-

I. In the US pacific northwest, transient stability including transient damping) have usually limited power transfer capability.
II. Also in recent years, the BC hydro has experienced limitations in power transfer capability in its service area of Vancouver, BC, during heavy winter load.
III. Again coming home, voltage stability is also a major concern in Lagos or Abuja area, the rapidly growing metropolitan communities in Nigeria, where peak power demands are increasing.

Also from the available literature and background studies, voltage instability or collapse or sag are characterized by the progressive fall of voltage which can take several forms [6].

- The inability of the network to meet a demand of the reactive power.
- Instability may be triggered by some form of disturbance, resulting in changes of the reactive power requirements.
- Disturbance may result from either small or large changes of essential load.

3.1 Detection and Prevention of Voltage Collapse or SAG

The process by which instability leads to loss of voltage in the significant parts of the system is the voltage collapse. While voltages may be lost due to "angle stability" as well, the phenomenon in many instances may be due to a deficit in reactive power generation, loss of critical lines, or degradation of control on key buses [5]. This calls for a new direction in power system to maintain substantially flat voltage profiles at all levels of ac transmission system, using the power system tool-box organized by Hadi sadat. The results indicated a balanced system. However, other preventive measures include, the use of optimal power flow strategy etc to minimize the voltage deviation.

4.0 LINE PERFORMANCE FOR 500KV, 180KM TRANSMISSION LINE ON NO-LOAD CONDITION, USING POWER SYSTEM TOOL-BOX

The power system tool box is that containing a set of M-files and was developed by Hadi Sadat to assist in typical power system analysis. Some of the programs, such as power flow, optimization, short-circuit and stability analysis were originated and developed by him for a main frame computer while working with power system consulting firms many years ago. These programs have been refined and standardized for interactive use with MATLAB for many problems related to the operations and analysis of power systems. The software modules are structured in such a way that the user may mix them for other power system analyses.

The M-files for typical power system analysis are designed to work in synergy and communicate with each other through the use of some global variables.

Line Performance Program

A program called **LinePerf** is developed for the complete analysis and compensation of a transmission line. The command **LinePerf** displays a menu with five options for the compensation of the parameters of the π models and transmission constants.

(I) Computer Analysis and Details for, 500kv, 180km Line Using Power System Tool-Box in Matlab for No-Load (Open-Circuited) with Shunt Reactor Compensation

3Φ line, 180KM long; Vs = 500KV (L – L); f = 50Hz.

Line parameters are as follows:

r = 0.016Ω/Km, L = 0.97mH/Km, C = 0.0115μF/Km.

Assume a lossless line.

The command:

>> LinPerf, displays the following menu

Transmission Line Model

Type of parameters for input	***Select***
Parameters per unit length r(ohms), g(siemens) L(mH) & C (micro F)	1
Complex z and y per unit length r+j*x (ohms/length), g+j*b (siemens/length)	2
Nominal pi or Eq. pi model	3
A, B, C, D constants	4
Conductor configuration and dimension	5
To quit	0

Select number of menu --> 1

Enter Line length = 30

Enter Frequency in Hz = 50

Enter line resistance/phase in ohms per unit length r = 0.016

Enter line inductance/phase in millihenry per unit length L= 0.97

Enter line capacitance/phase in micro F per unit length C=0.0115

Enter line conductance/phase in siemens per unit length g= 0

Enter 1 for Medium line or 2 for long line --> 1

Nominal pi model

Z = 0.48 + j 9.14203 ohms

Y = 0 + j 0.000108385 Siemens

ABCD =

0.9995 + j 2.6012e-005 0.48 + j 9.142

-1.4097e-009 + j 0.00010836 0.9995 + j 2.6012e-005

Hit return to continue

At this point the program list menu is automatically loaded and displays the following menu

Transmission Line Performance

Analysis	***Select***
To calculate sending end quantities for specified receiving end MW, Mvar	1
To calculate receiving end quantities for specified sending end MW, Mvar	2
To calculate sending end quantities when load impedance is specified	3

Open-end line & inductive compensation 4

Short-circuited line 5

Capacitive compensation 6

Receiving end circle diagram 7

Loadability curve and voltage profile 8

To quit 0

Select number of menu --> 4

Enter sending end line-line voltage kV = 500

Enter receiving end voltage phase angleø (for Ref. enter 0) = 0

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 500.248 kV (L-L) at -2.60253e-005ø

Is = 31.2958 A at 89.9993ø PFs = 1.30159e-005 leading

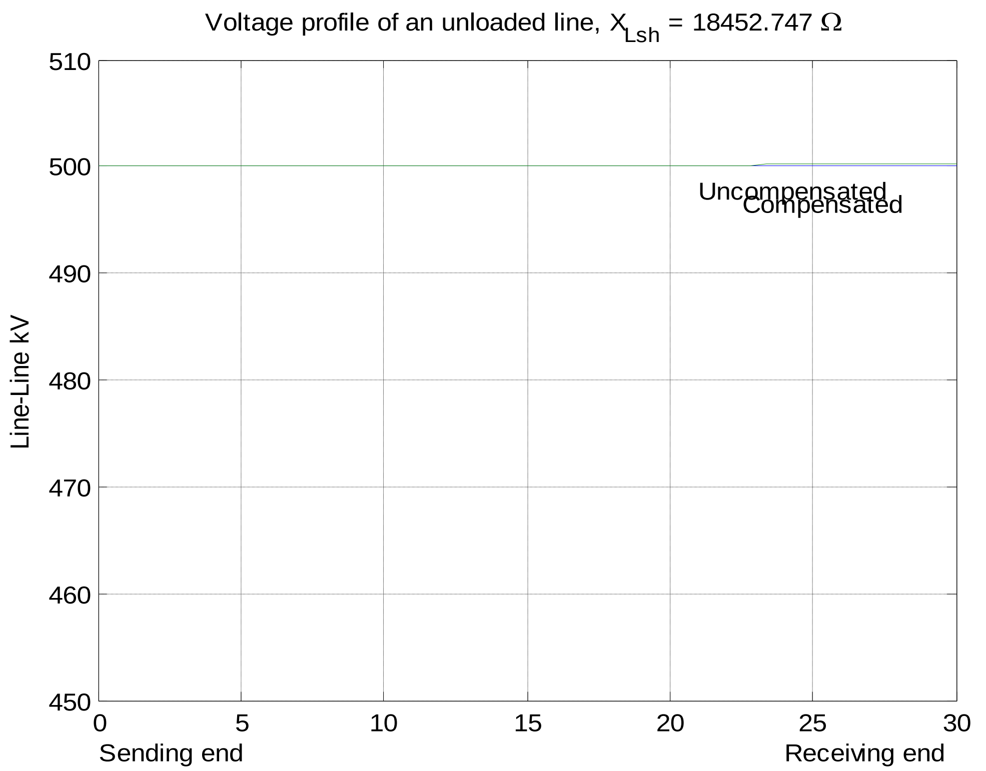
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 18452.7 ohm

Shunt reactor rating = 13.5481 Mvar

Hit return to continue



ISSN: 2278-6244
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Similar other values and voltage profiles were obtained for: **60km**

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 500.993 kV (L-L) at -0.000104256ø

Is = 62.6382 A at 89.997ø PFs = 5.21798e-005 capacitive leading

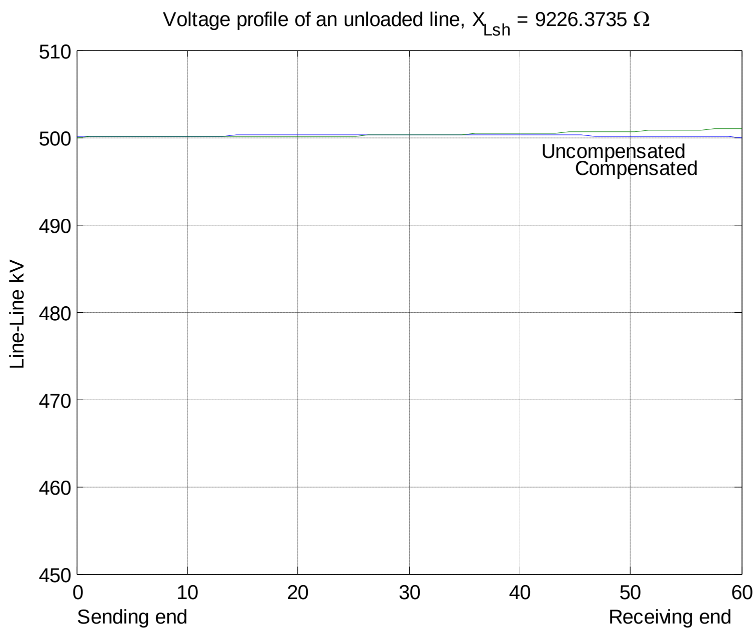
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 9226.37 ohm

Shunt reactor rating = 27.0962 Mvar

Hit return to continue



90km

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 502.239 kV (L-L) at -0.00023516ø

Is = 94.0743 A at 89.9932ø PFs = 0.000117843 leading

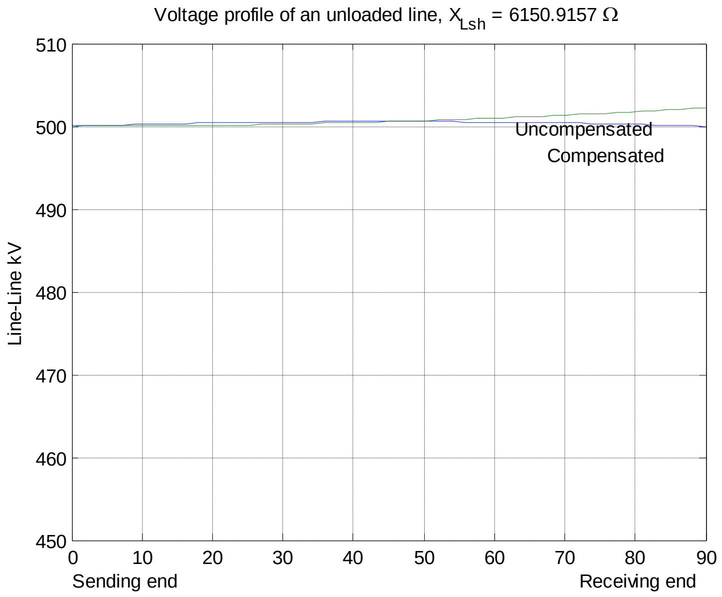
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 6150.92 ohm

Shunt reactor rating = 40.6444 Mvar

Hit return to continue



120km

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 503.995 kV (L-L) at -0.000419524ø

Is = 125.652 A at 89.9879ø PFs = 0.000210597 leading

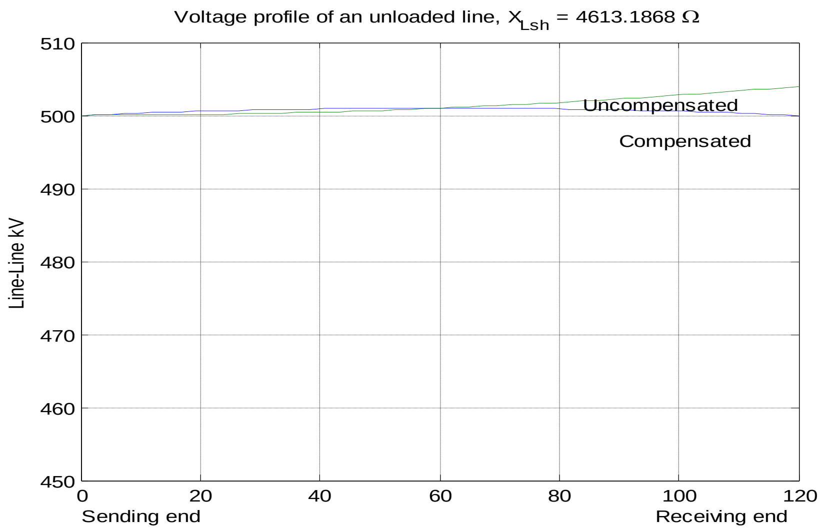
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 4613.19 ohm

Shunt reactor rating = 54.1925 Mvar

Hit return to continue



150km

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 506.27 kV (L-L) at -0.000658465ø

Is = 157.421 A at 89.981ø PFs = 0.000331284 leading

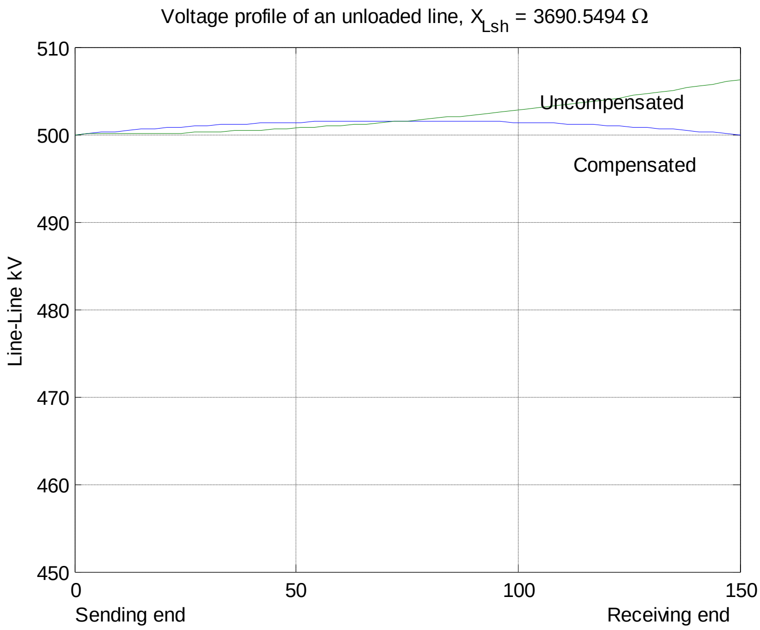
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 3690.55 ohm

Shunt reactor rating = 67.7406 Mvar

Hit return to continue



180km

Open line and shunt reactor compensation

Vs = 500 kV (L-L) at 0ø

Vr = 509.079 kV (L-L) at -0.000953451ø

Is = 189.433 A at 89.9724ø PFs = 0.000481015 leading

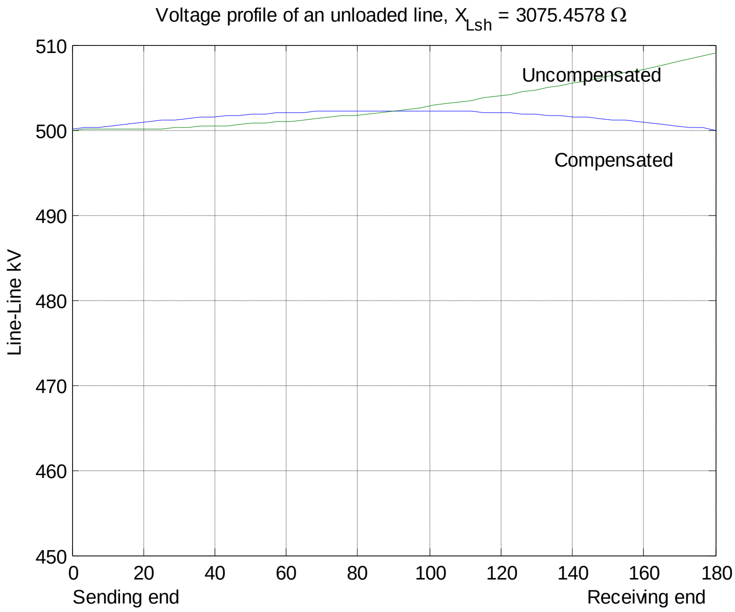
Desired no load receiving end voltage with shunt reactor compensation kV (L-L) = 500

Desired no load receiving end voltage = 500 kV

Shunt reactor reactance = 3075.46 ohm

Shunt reactor rating = 81.2887 Mvar

Hit return to continue



(II) Results

Table 4.1: Showing the results of shunt reactor compensation details for 500KV, unloaded 180KM line (open circuited).

Line Performance for Specified Receiving end Quantities

BEFORE COMPENSATION			AFTER COMPENSATION					
TRANS= MISSION DISTANCE		TR. LINE PARAMETERS				DESIRED N0 LOAD	SHUNT REACTOR	SHUNT
LENGTH OF LINE	CUMU-LATIVE LENGTH OF LINE	PER PHASE r = 0.016Ω/KM L=0.97`MH/KM C=0.0115μl/KM				RECEV. END VOLTAGE	REACTANCE X_{LSH}	REACTOR RATING
(K_M)	(K_M)	V_S (KV)	I_S(A)	V_R(K_V)	I_R(A)	(K_V)	(Ω)	(M_{VAR})
0	30	500	$21.31\angle 90^0$	500.248	0	500	18446.83	13.550
30								
	60	500	$62.66\angle 90^0$	500.992	0	500	9223.69	27.104
60								
	90	500	$91.15\angle 90^0$	502.238	0	500	6146.02	40.677
90								
	120	500	$125.83\angle 90^0$	503.990	0	500	4606.63	54.270
120								
	150	500	$157.75\angle 90^0$	506.528	0	500	3682.87	67.882
150								
	180	500	$190.00\angle 90^0$	509.050	0	500	3066.72	81.520
180								

(III) Observations

The voltage profiles of the compensated lines are substantially flat, almost at all levels of the transmission line, although beyond 120km or more, experienced little divergence. This can be eliminated by ensuring that the var demand of the load must be met locally by employing positive var generator (Condenser).

Again from table 4.1, Mvar demand (reactive power) increase as the line length increases, and if the var demand is large, the voltage profile at that point tends to sag rather sharply while the compensated and uncompensated profiles diverge more and more as the line length increases.

Moreover, with the constant sending-end voltage (Vs) at 500KV (see the table), the receiving-end voltage will continue to rise with increase in the line length until a quarter of wavelength ($\lambda/4$) or 1200Km is attained, when the rise becomes infinitely high. And beyond this value to about 1500Km, it may even turn to negative. This rise in voltage at the receiving end is due to the flow of line charging capacitive current through the line inductance. This phenomenon is called Ferranti effect.

5.0 CONCLUSION

From the analysis results, reactive power compensation not only maintain substantially flat voltage profiles at all levels of a.c. transmission system as can be seen from the figures in 30km – 180KM lines, the result is that it increases the transmission line efficiency, maintains steady state and temporary over-voltage, and can avoid disastrous blackouts.

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