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Power Tapping Of Upgrade Transmission Line by Using Composite Ac-Dc Power Transmission Lines

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Abstract:- Long extra high voltage (EHV) ac lines cannot be loaded to their thermal limits in order to keep sufficient margin against transient instability. With the scheme proposed in this paper, it is possible to load these lines very close to their thermal limits. The conductors are allowed to carry usual ac along with dc superimposed on it. The added dc power flow does not cause any transient instability. This paper gives the feasibility of converting a double circuit ac line into composite ac–dc power transmission line to get the advantages of parallel ac–dc transmission to improve stability and damping out oscillations. Simulation and experimental studies are carried out for the coordinated control as well as independent control of ac and dc power transmissions. No alterations of conductors, insulator strings, and towers of the original line are needed. Substantial gain in the load ability of the line is obtained. Master current controller senses ac current and regulates the dc current orders for converters online such that conductor current never exceeds its thermal limit
.

Key words:- SIMULINK simulation, simultaneous ac–dc power transmission, small power tapping.

I. INTRODUCTION

In recent years, public has become more sensitive to the proliferation of overhead transmission right-of-ways. Industrial countries are experiencing increasing difficulty in finding suitable corridors for new overhead transmission lines and in many cases it is simply impossible. There is an increasing pressure to provide the substantial power upgrading of existing ac transmission line corridors. Two possible suggestions discussed in reference [1, 2] for power upgrading of existing ac transmission are:

- Appropriate modification to existing ac lines without major new construction with increased voltage level either ac or dc.
- Elimination of the old existing HV/EHV ac lines and their substitution with new lines of EHV/UHV ac or HVDC. This would amount to major change.

A third possibility in reference [3] suggests addition of more circuits onto existing right-of-ways. Among many possibilities to implement this idea, one used by Ontario Hydro and others [3], refers to restructuring existing lower voltage transmission or distribution circuits onto new towers with new high-voltage circuits. That is, forcing many electric utilities to utilize existing corridors by upgrading existing right-of-way (RoW). This will be far cheaper than going for underground transmission. In all these suggestions, major changes are required to get substantial power upgrading of transmission line.

Recently proposed concept of simultaneous ac-dc power transmission enables the long EHV ac lines to be loaded close Dr. H. Rahman is with the Faculty of Engineering, King Khalid University, Kingdom of Saudi Arabia (Email: hrahman1@rediffmail.com / hrahman1in@yahoo.co.in) to their thermal limits. The conductors are allowed to carry certain amount of dc current superimposed on usual ac [5].The novelty of the present work demonstrates the substantial power upgrading of an existing EHV ac lines by converting it into composite ac-dc line. No alterations of conductors, insulator strings and tower structures of the original EHV ac line are required in this case.

From this composite ac–dc line, small power tapping is also possible despite the presence of a dc component in it. This paper proposes a simple scheme of small power tapping from the composite ac–dc power transmission line along its route. In this study, the tapping stations are assumed to draw power up to 10% of the total power transfer capability of the composite line. However, more power tapping is also possible subject to the condition that it is always less than the ac power component.

II. CONCEPT OF SIMULTANEOUS AC-DC POWER TRANSMISSION

In simultaneous ac-dc power transmission system, the conductors are allowed to carry dc current superimposed on ac current. AC and DC power flow independently and the added dc power flow does not cause any transient instability [6]. The network in Fig. 1 shows the basic scheme for simultaneous ac-dc power flow through a double circuit ac transmission line. The dc power is obtained by converting a part of ac through line commutated 12-pulse rectifier bridge used in conventional HVDC and injected into the neutral point of the zig-zag connected secondary windings of sending end transformer. The injected current is distributed equally among the three windings of the transformer. The same is reconverted to ac by the conventional line commutated inverter at the receiving end. The inverter bridge is connected to the neutral of zig-zag connected winding of the receiving end transformer. Each transmission line is connected between the zig-zag windings at both ends. The double circuit transmission line carries both 3-phase ac as well as dc power. At both ends, zig-zag connection of secondary windings of transformer is used to avoid saturation of core due to flow of dc component of current.

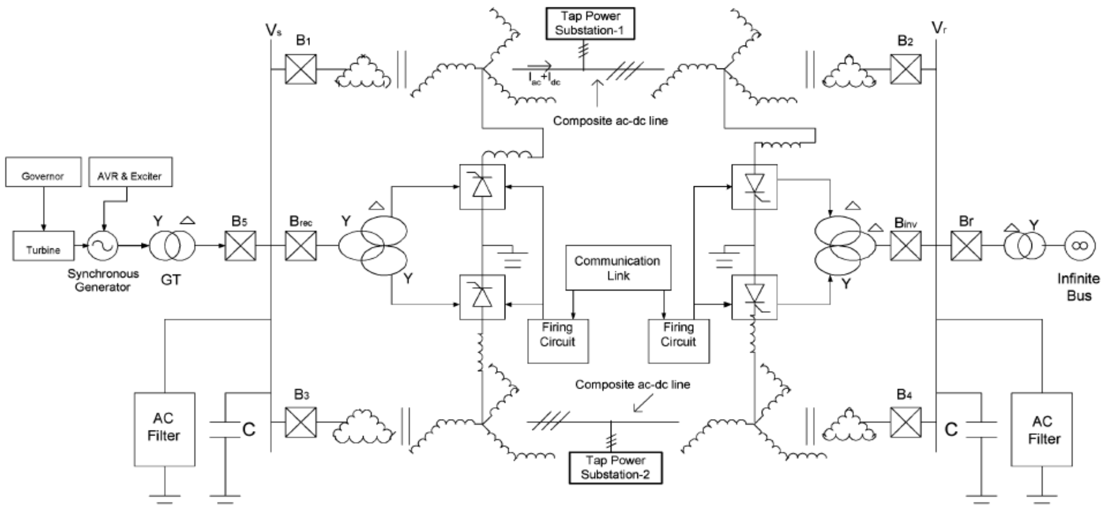

Fig.1. Single-line diagram of (a) basic composite ac-dc transmission system

II. SMALL POWER TAPPING STATION REQUIREMENTS

The main requirements of a small power tapping stations are as follows.

- The per unit cost of the tap must be strongly constrained (i.e., the fixed cost must be kept as low as possible).
- The tap must have a negligible impact on the reliability of the ac–dc system. This implies that any fault in the tap must not be able to shutdown the whole system.
- The tap controls should not interfere with the main system (i.e., the tap control system has to be strictly local). Failure to achieve this leads to a complex control system requirement and, thus, higher cost of hardware.
- Small tap stations having a total rating less than 10% of the main terminal rating have potential applications where small, remote communities or industries require economic electric power [7]–[9].

The tapping stations considered in this study are of fairly small power rating, up to 10% of the total transfer capacity of the composite ac-dc power transmission line. Short interruption of the power supplies should be tolerable at the occurrence of temporary earth faults on the main simultaneous ac–dc power transmission system. Further, any fault occurring within tapping station and its local ac network is to be cleared by local CBs. These tapping stations will not depend upon the telecommunication links with the main composite ac–dc transmission system.

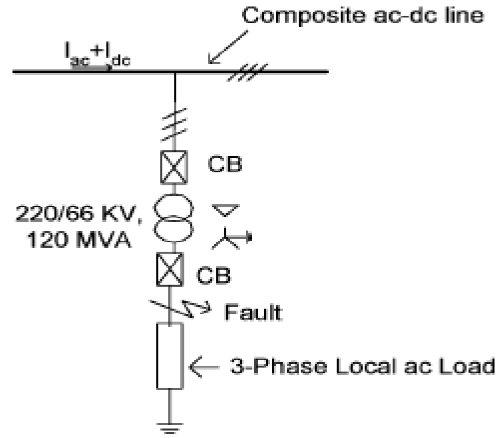

Fig. 2. Single-line diagram of power tap substation.

III. DESCRIPTION OF THE SYSTEM MODEL

A synchronous machine is feeding power to infinite bus via a double circuit,three-phase,400KV,50Hz, 450Km ac transmission line. The 2750MVA,24KV synchronous machine is dynamically modeled, a field coil on d-axis and a damper coil on q-axis, by Park's equations with the frame of reference based in rotor. It is equipped with an IEEE type AC4A excitation system of which block diagram is shown in Fig. 3. Transmission lines are represented as the Bergeron model. It is based on a distributed LC parameter traveling wave line model, with lumped resistance. It represents the L and C elements of a PI section in a distributed manner (i.e., it does not use lumped parameters).

It is roughly equivalent to using an infinite number of PI sections, except that the resistance is lumped (1/2 in the middle of the line, 1/4 at each end). Like PI sections, the Bergeron model accurately represents the fundamental frequency only. It also represents impedances at other frequencies, except that the losses do not change. This model is suitable for studies where the fundamental frequency load flow is most important. The converters on each end of dc link are modeled as line commutated two six- pulse bridge (12-pulse), Their control system consist of constant current (CC) and constant extinction angle (CEA) and voltage dependent current order limiters (VDCOL) control. The converters are connected to ac buses via Y-Y and Y- converter transformers. Each bridge is a compact power system computer-aided design (SIMULINK) representation of a dc converter, which includes a built in six-pulse Graetz converter bridge (can be inverter or rectifier), an internal phase locked oscillator (PLO), firing and valve blocking controls, and firing angle /extinction α angle γ measurements. It also includes built in RC snubber circuits for each thyristor. The controls used in dc system are those of CIGRE Benchmark, modified to suit at desired dc voltage. Ac filters at each end on ac sides of converter transformers are connected to filter out 11th and 13th harmonics. These filters and shunt capacitor supply reactive power requirements of converters. A master current controller (MCC), shown in Fig. 3, is used to control the current order for converters. It measures the conductor ac current, computes the permissible dc current, and produces dc current order for inverters and rectifiers.

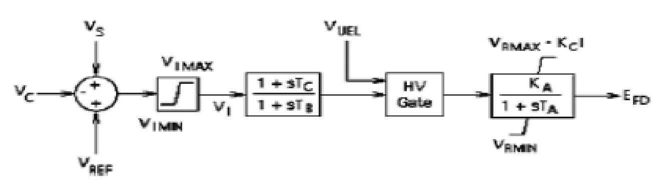

Fig. 3. IEEE type AC4A excitation system.

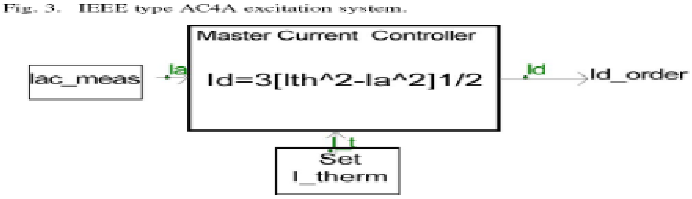

Fig. 4 Master current controller

IV. EFFECT OF LINE CAPACITANCE

Simultaneous ac-dc transmission has a significant advantage over HVDC transmission due to its ability to utilize the line capacitance. In pure HVDC system, capacitance of transmission line cannot be utilized to compensate inductive VAR, as the dc line voltage is constant with time. The rectifier and inverter bridges consumes lagging VAR (about 50% to 60% that of active power) for their operation. This VAR requirement increases with gate firing angle of thyristors. The VAR of the converter in addition to lagging VAR of load is to be supplied by synchronous condenser or static capacitor.

In simultaneous ac – dc power transmission, the superimposed ac-dc voltage varies with time and the transmission line capacitance appears as shunt admittance to converter and in parallel to the load. For example 400KV, 500Km, 3-phase transmission line having shunt admittance of $y=j3.3797*10^{-6}$ mho/ph/Km, the total leading VAR available is 270.378MVA ($3.3797*10^{-6}*500*400^2$). For long EHV line when receiving end power is less than its natural load there is an excess of line charging; Qs is negative and Qr is positive. This huge amount of leading VAR compensates partly or fully the lagging VAR requirement of converter and load. But it remains latent in HVDC transmission

V. SIMULATION OF THE PROPOSED SCHEME

In order to examine the feasibility of the proposed scheme for power tapping and to observe the performance of the composite ac-dc power transmission system under various operating conditions, in MATLAB/SIMULINK software simpower system was used. The initial operating conditions of the simultaneous ac–dc power transmission system before the tapping power is switched on are the following:
ac power at the receiving end P_{ac} = 603.735 MW
dc power at the receiving end P_{dc} = 1560.083 MW
total power transfer at the receiving end $P_{total\text{-}transfer}$ = 2162.9 MW
transmission angle = 60^0

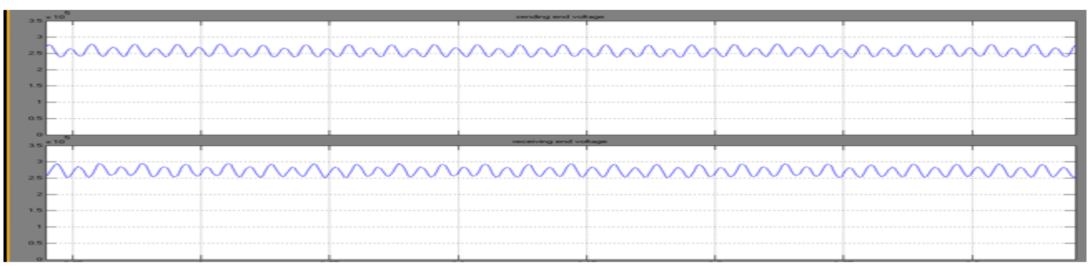

Fig.5 Sending end voltage and receiving end voltage

fig.6 Sending end current and receiving end current

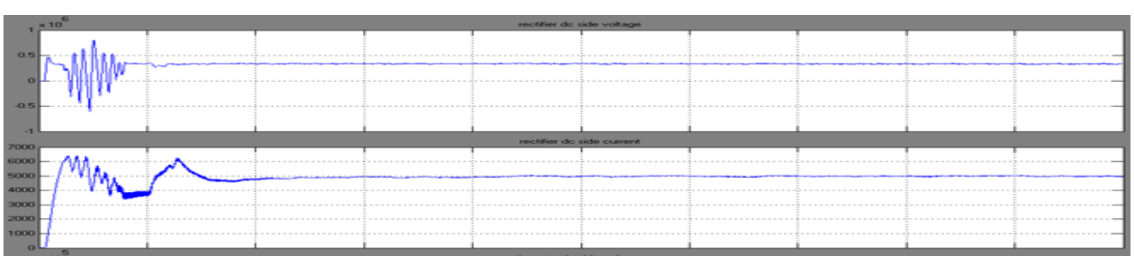

Fig.7 Rectifier DC side voltage and current

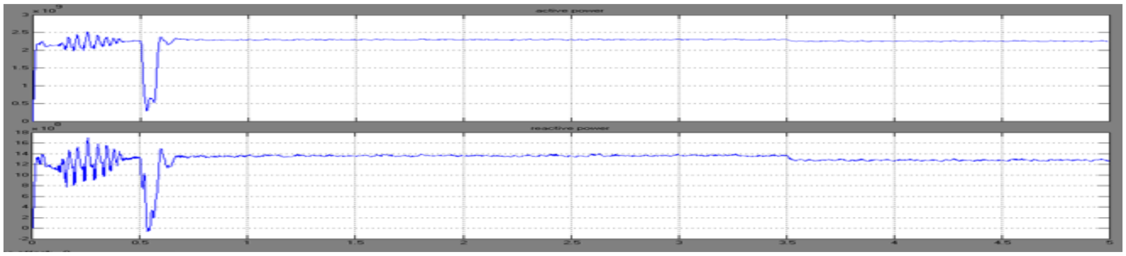

Fig.8 Active power and reactive power

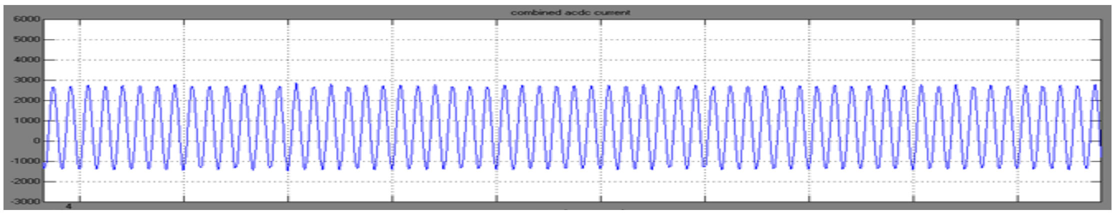

Fig.9 Combined ac-dc currents

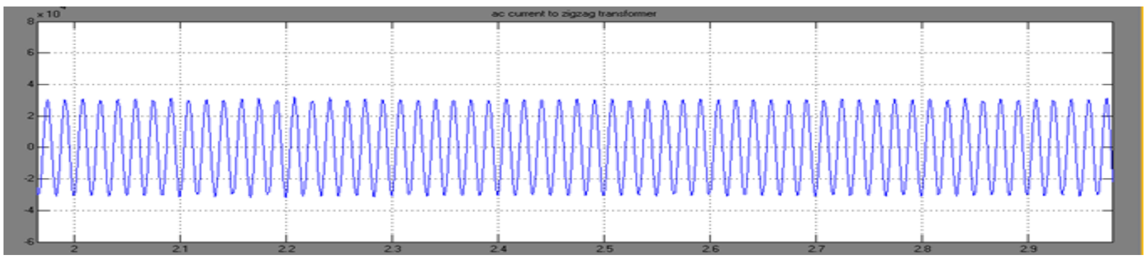

Fig.10 ac current to zigzag transformer

VI. CONCLUSION

The merits to convert existing double circuit ac transmission line to composite ac-dc transmission line for substantial power upgrading have been demonstrated. For the particular system studied, there is substantial increase in the loadabilty of the line. The loadabilty further increases with increase in the length of line. The line is loaded to its thermal limit with the superimposed dc current. The dc power flow does not impose any stability problem. The stability aspects up to 80^0 power angle have been reported in reference [6]. No modification is required in the size of conductors, insulator strings and towers structure of the original line.

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