Power upgrading of Transmission Line by combining AC-DC Transmission

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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 project, 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 **- Flexible ac transmission system (FACTS) , Extra high voltage (EHV)transmission, power system computer-aided design(PSCAD), Simultaneous ac-dc power transmission.**

1. Introduction:

In recent years, environmental, right-of-way, and cost concerns have delayed the construction of a new transmission line, while demand of electric power has shown steady but geographically uneven growth. The power is often available at locations not close to the growing load centre but at remote locations. These locations are largely determined by regulatory policies, environmental acceptability, and the cost of available energy. The wheeling of this available energy through existing long ac lines to load centre has a certain upper limit due to stability considerations. Thus, these lines are not loaded to their thermal limit to keep sufficient margin against transient instability. The present situation demands the review of traditional power transmission theory and practice, on the basis of new concepts that allow full utilization of existing transmission facilities without decreasing system availability and security. The flexible ac transmission system (FACTS) concepts, based on applying state-of-the-art power electronic technology to existing ac transmission system, improve stability to achieve power transmission close to its thermal limit. The basic proof justifying the simultaneous ac–dc power transmission is explained in an IEEE paper“Simultaneous ac-dc power transmission,” by K. P. Basu and B. H. Khan. In the above reference, simultaneous ac–dc power transmission was first proposed through a single circuit ac transmission line. In these proposals Mono-polar dc transmission with ground as return path was used. There were certain limitations due to use of ground as return path. Moreover, the instantaneous value of each conductor voltage with respect to ground becomes higher by the amount of the dc voltage, and more discs are to be added in each insulator string to withstand this increased voltage. However, there was no change in the conductor separation distance, as the line-to-line voltage remains unchanged. In this paper, the feasibility study of conversion of a double circuit ac line to composite ac–dc line without altering the original line conductors, tower structures, and insulator strings has been presented.

2. Problem Definition:-

The main object of my paper is to show that by superimposing DC in AC transmission, the capacity of the transmission line can be increased by nearly 70 % of that if only AC is transmitted. In our existing transmission system, 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 project, 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.

3. Literature Survey:-

This report presents the Power Upgrading of Transmission line by combining AC and DC transmission. The flexible ac transmission system (FACTS) concepts, based on applying state-of-the-art power electronic technology to existing ac transmission system, improve stability to achieve power transmission close to its thermal limit [1]–[4].

Another way to achieve the same goal is simultaneous ac–dc power transmission in which the conductors are allowed to carry superimposed dc current along with ac current. Ac and dc power flow independently, and the added dc power flow does not cause any transient instability. The authors, H. Rahman and B. H. Khan, of this paper have earlier shown that extra high voltage (EHV) ac line may be loaded to a very high level by using it for simultaneous ac–dc power transmission as reported in references [5] and [6]. The basic proof

justifying the simultaneous ac–dc power transmission is explained in reference [6]. In the above references,

simultaneous ac–dc power transmission was first proposed through a single

circuit ac transmission line. In these proposals Mono-polar dc transmission with ground as return path was used. There were certain limitations due to use of ground as return path. Moreover, the instantaneous value of each conductor voltage with respect to ground becomes higher by the amount of the dc voltage, and more discs are to be added ineach insulator string to withstand this increased voltage. However, there was no change in the conductor separation distance, as the line-to-line voltage remains unchanged. In this paper, the feasibility study of conversion of a double circuit ac line to composite ac–dc line without altering the original line conductors, tower structures, and insulator strings has been presented. In this scheme, the dc power flow is point-to point bipolar transmission system. Clerici*et al.* [7] suggested the conversion of ac line to dc line for substantial power upgrading of existing ac line. However, this would require major changes in the tower structure as well as replacement of ac insulator strings with high creepage dc insulators. The novelty of our proposed scheme is that the power transfer enhancement is achieved without any alteration in the existing EHV ac line. The main object is to gain the advantage of parallel ac–dc transmission and to load the line close to its thermal limit.

4. Existing Transmission Issues and Solution

4.1 High Voltage DC Transmission:-

4.1.1 Introduction:-

It has been widely documented in the history of the electricity industry, that the first commercial electricity generated (by Thomas Alva Edison) was direct current (DC) electrical power. The first electricity transmission systems were also direct current systems. However, DC power at low voltage could not be transmitted over long distances, thus giving rise to high voltage alternating current (AC) electrical systems. Nevertheless, with the development of high voltage valves, it was possible to once again transmit DC power

at high voltages and over long distances, giving rise to HVDC transmission systems. Since the first commercial installation in 1954 a huge amount of HVDC transmission systems have been installed around the world. In today electricity industry, in view of the liberalization and increased effects to conserve the environment, HVDC solutions have become more desirable for the following reasons:
1. Environmental advantages
2. Economical (cheapest solution)
3. Asynchronous interconnections
4. Power flow control
5. Added benefits to the transmission
(stability, power quality etc.)

4.1.2 Inherent problems associated with HVDC:

(a) Expensive converters:
Expensive Converter Stations are required at each end of a D.C. transmission link, whereas only transformer stations are required in an A.C. link.
(b) Reactive power requirement: Converters require much reactive power, both in rectification as well as in inversion. At each converter the reactive power consumed may be as much at 50% of the active power rating of the D.C. link. The reactive power requirement is partly supplied by the filter capacitance, and partly by synchronous or static capacitors that need to be installed for the purpose**.**
(c) Generation of harmonics: Converters generate a lot of harmonics both on the D.C. side and on the A.C. side. Filters are used on the A.C. side to reduce the amount of harmonics transferred to the A.C. system. On the D.C. system, smoothing reactors are used. These components add to the cost of the converter.
(d) Difficulty of circuit breaking: Due to the absence of a natural current zero with D.C., circuit breaking is difficult. This is not a major problem in single HVDC link systems, as circuit breaking can be accomplished by a very rapid absorbing of the energy back into the A.C. system. (The blocking action of thyristors is faster than the operation of mechanical circuit breakers). However the lack of HVDC circuit breakers hampers multi-terminal operation.

4.2 High Voltage AC Transmission:-

4.2.1 Introduction:-
Industrial-minded countries of the world require a vast amount of energy of which electrical energy forms a major fraction. The world has already consumed major portion of its natural resources and is looking for sources of energy other than Hydro and Thermal to cater for the rapid rate of consumption which is outpacing the discovery of new resources. This will not slow down with time and therefore there exists a need to reduce the rate of annual increase in energy consumption by any intelligent society if resources have to be preserved for posterity. This requires very high voltages for transmission. The very rapid stride taken by development of dc transmission since 1950 is playing a major role in extra-long-distance transmission, complementing or supplementing E.H.V. ac transmission. They have their roles to play and a country must make intelligent assessment of both in order to decide which is best suited for the country's economy.

4.2.2 Problems posed in using such HVAC are encountered as:-

(*a*) Increased Current Density because of increase in line loading by using series capacitors.
(*b*) Use of bundled conductors.
(*c*) High surface voltage gradient onconductors.
(*d*) Corona problems: Audible Noise, Radio Interference, Corona Energy Loss, Carrier Interference, and TV Interference.
(*e*) High electrostatic field under the line.
(*f*) Switching Surge Over voltage’s which cause more havoc to air-gap insulation than lightning or power frequency voltages.
(*g*) Increased Short-Circuit currents and possibility of Ferro resonance conditions.

(*h*) Use of gapless metal-oxide arresters replacing the conventional gap-type Silicon Carbide arresters, for both lightning and switching-surge duty.
(*i*) Shunt reactor compensation and use of series capacitors, resulting in possible sub synchronous resonance conditions and high short circuit currents.

4.3 Proposed System (Simultaneous AC-DC Power Transmission):-

With the scheme proposed in this thesis, it is possible to load the transmission 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 thesis 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. 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. In this thesis, the feasibility study of conversion of a single circuit ac line to composite ac–dc line without altering the original line conductors and tower structures has been presented.

4.3.2 Proof with Equations:-

Neglecting the resistive drops in the line conductors and transformer windings due to dc current, expressions for ac voltage and current, and for active and reactive powers in terms of A, B, C, and D parameters of each line may be written as

ES = AER + BIR IS = CER + DIR [4.2]

$PS + j\,QS = -E_S E_R / B^* + [D^* E_s^2 / B^*]$ [4.3]

$PR + j\,QR = E_R E_S / B^* - [A^* E_R^2 / B^*]$ [4.4]

Neglecting ac resistance drop in the line and transformer, the dc power Pdr and Pdi of each rectifier and inverter are given by Pdr = Vdr Id [4.5]

Pdi = Vdi Id [4.6]

Reactive powers required by the converters

Are $Qdr = Pdr \tan \theta r$ [4.7]

$Qdi = Pdi \tan \theta i$ [4.8]

The net current ′I′ in any conductor is off seted from zero. In case of a fault in the transmission system, gate signals to all the SCRs are blocked and that to the bypass SCRs are released to protect rectifier and inverter bridges. The current in any conductor is no more offseted. Circuit breakers (CBs) are then tripped at both ends to isolate the faulty line. CBs connected at the two ends of transmission line interrupt current at natural current zeroes, and no special dc CB is required.

5. Series D-FACTS controller:-

The transmission lines reactance is assumed to be purely inductive in nature. The impedance of line can be changed by injection of series passive capacitive or inductive elements in the transmission line and power flow transfer can be changed [7, 18, 19]. D-FACTS device can be used to change the series impedance of transmission line. D-FACTS are the advanced FACTS technology which is distributed over the whole transmission line as small modules between the small span of transmission lines as seen in figure-1. and they can offer series capacitive or inductive reactance in the line through STT [3,20].

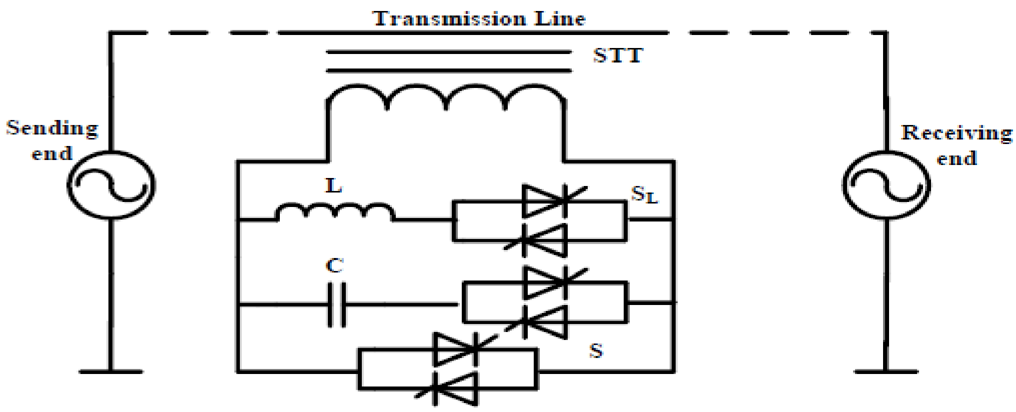

Figure 3. Simplified schematic of a D-FACTS device

Comparison between FACTS and D-FACTS on the basis of weight and power:-

Constraints	Conventional FACTS	D-FACTS
Power rating	10-300 MVA per module	10 kVA per module
Weight	280-300 kg /10 kVA (average data)	50-60 kg. per module

6. Conclusion:-

The feasibility to convert ac transmission line to a composite ac–dc line has been demonstrated. For the particular system studied, there is substantial increase (about 83.45%) in the loadability of the 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 advantage of parallel ac–dc transmission is obtained. Dc current regulator may modulate ac power flow. There is no need for any modification in the size of conductors, insulator strings, and towers structure of the original line. The optimum values of ac and dc voltage components of the converted composite line are ½ and $1/\sqrt{2}$ times the ac voltage before conversion, respectively.

7.2 Future Scope

In this paper, it is shown that by injecting DC power in AC power transmission lines, we can improve the transmission capacity of the line by 2 to 4 times without altering the physical equipment. This work can be extended for analysing the effect of faults on this type of transmission. This work is done on double circuit AC transmission lines but it can be extended to other types of transmission methods.

References:

1. L. K.

Gyugyi, "Unified power flow concept for flexible A.C. transmission system," Proc. Inst. Elect. Eng., p.323, Jul. 1992.

2. L. K.

Gyugyi et al., "The unified power flow controller; a new approach to power transmission control," IEEE Trans. Power Del., vol. 10, no. 2, pp. 1085–1097, Apr. 1995.

3. N. G.

Hingorani, "FACTS—flexible A.C. transmission system," in Proc. Inst. Elect. Eng. 5th. Int. Conf. A.C. D.C. Power Transmission, London, U.K.,

4. K. P.

Basu and B. H. Khan, ″Simultaneous ac-dc power transmission,″ Inst. Eng. (India) J.-EL, vol. 82, pp. 32–35, Jun. 2001.

5.R. K. Varma, (2009) "Introduction to FACTS Controllers", *Power Systems Conference and Exposition, Seattle, USA,* Vol. 9, pp. 1-6.

6. S. K. Shrivastva, (2010) "Advanced Power Electronics Based FACTS Controllers: An Overview", *Asian Power Electronics Journal*, Vol. 4. pp. 90-95.