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Controlling of Power Transformer Tap Positions (OLTC) Using Facts Devices

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Abstract:* Modern power system needs to monitor the power transformer frequently. In an earlier years mechanical types of on load transformer is used. The mechanical transformer tap changes is consists of following issues like manpower, arcing, frequent maintenance, also service costs. To overcome those power electronic as well as solid state tap changers were developed. It deals with power semiconductor devices like as IGBT (Insulated Gate bipolar Transistor) TRIAC, which allows to develop the quick operating on load tap positions. This power semiconductor is helpful for fixing flicker and sags. By varying the tap positions the voltage is controlled by FACTS devices. The control devices along with power electronic devices is connected with AVR (Automatic Voltage Regulator). The FACTS based power transformer is control the tap positions by injecting the voltage is taken from the receiving side of power transformer. This injecting voltage compared with predefined voltage in ALTC device. FACTS devices are installed in AC transmission grid to increase voltage regulation, grid stability, and controllability of the tap positions of transformer through series and/or shunt compensation using capacitor banks. These capacitor banks are connected to the transmission system using breakers. The main purpose of the automatic load tap changing for power transformers is to keep the voltage on lower voltage side of power transformer within a preset deadband.

***Keywords:* On-Load Tap Changer; FACTS; AVR; Power Transformer; Tap Change Positions; MATLAB Simulation**

I. INTRODUCTION

The management of OLTC is employed for higher voltage regulation. The changes in transformer tap according demand of input voltage changes that is from generating aspect. The employment of mechanical tap changer made several issues like arcing, high maintenance, slow latency and frequent maintenance. In order to cut back the on top of mentioned problems is huge challenge to eliminate those drawbacks with the automatic voltage contacts of OLTC. By inserting MOSFET, GTO, IGBT and along with power transformer, the transformer tap positions gets increasing and decreasing. These changes will increase the potency of the steady state system. For up the voltage stability and quality within the receiving aspect OLTC is provided with FACTS devices. The FACTS devices brings additional reliable for increasing the speed of switch operations furthermore as scale back the arcing. The advantage of mistreatment solely TRAIC is it will act in each positive and negative cycle. As switch of TRAIC will be done at zero degree firing angle there will no issue of harmonics. This transformer control circuit mounted outside the ability electrical device. The ability physics devices area unit the sleek operational devices and have higher potency supply voltage. Overall use of power electronic devices can facilitate to boost performance of existing assets and build the grid additional robust within the event of disruptions. Essentially AVR was designed to catch up on the free fall across power electrical device resistivity caused by flow of the load current. According to [1] "*Using transformers and tap changers to see how the voltage works in an electric system and analyze the relationships with other aspects of the system's performance, like power losses or tap changer operation*." To overcome all these problems, we propose an Automatic voltage control of load using OLTC in this paper. This paper consists of Existing system in section II, Proposed system in section III, simulation diagram in section VII, Followed by conclusion in section VIII.

II. EXISTING SYSTEM OF ON AND OFFLOAD TAP CHANGING

The circuit diagram shows the traditional diagram of mechanical tap changing. It consists of primary and secondary windings. By varying the tap positions able to get the desirable output voltage within the receiving aspect. The contacts in mechanical switch it produces arcing issues. Therefore, so as to cut back we tend to area unit in want of frequent maintenance. This arcing needs additional cooling strategies it cause additional cost.

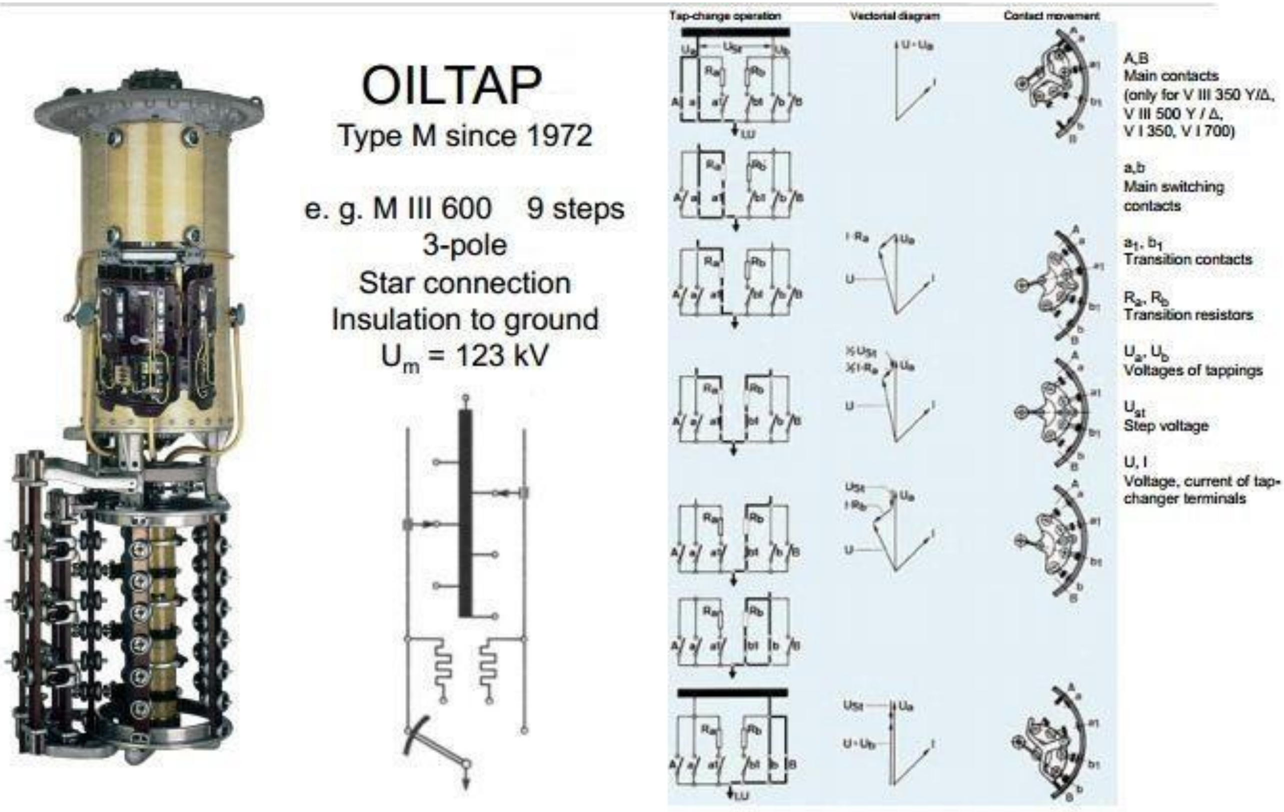


Fig 1. Mechanical switch of Tap changing transformer

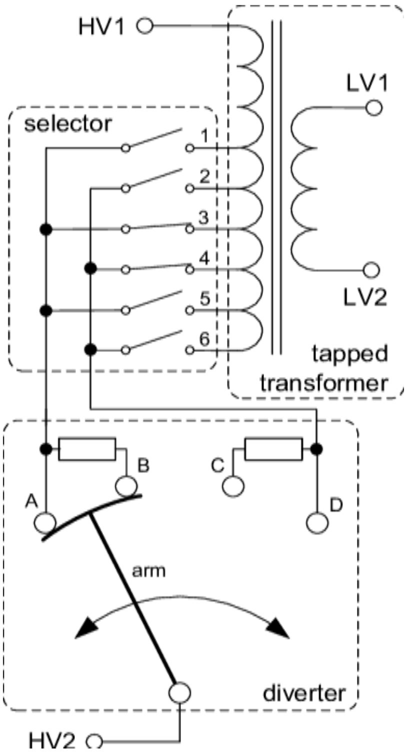


Fig 2. A simplified view of the classic mechanical-OLTC

III. PROPOSED SYSTEM OF ON AND OFFLOAD TAP CHANGING

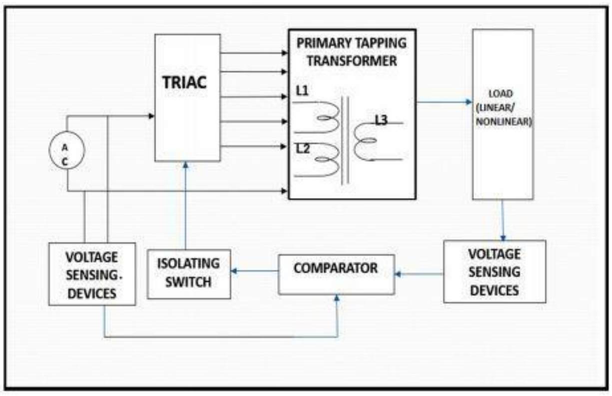


Fig 3. Proposed system of on and off load tap changing

A. *Voltage Sensing Instruments*

The voltage sensing instruments area unit like noble metal electrical device. It is connected in each side of power transformer like primary and secondary side. This voltage sensing instrument can compare with its gift esteem given to the AVR.

B. *Power Transformer*

For reducing switch losses primary tapings area unit designed. This power electrical device consists of primary and secondary windings. The tap position within the electrical device is management the voltage.

C. *FACTS*

The high speed switch devices area unit accustomed management the voltage. The FACTS devices area unit TRIAC, IGBT. It will be used as a region of circuits for repeat amendment, voltage alter and management. It is a speedier reaction which is able to terribly facilitate with exchanging.

D. *Real and Reactive source (P and Q)*

AC voltage is given to the AVR that is connected to the OLTC for control the voltage constant. The control voltage is reassuring the security to humans, eliminating the arcing problems furthermore as give safety for equipments. The employment of voltage sensing instruments detects the voltage of primary and secondary aspect of power electrical device. This voltage with power physics devices helps to boost the right voltage regulation. This is often achieved by injecting the Reactive power (Q) by mistreatment the breaker open and shut switch.

IV. VOLTAGE CONTROL WITH ON-LOAD TAP-CHANGER USING ATC

The voltage management is achieved by turns magnitude relation. Depends upon the turns, magnitude relation the ability electrical device acts as step up or step down transformer. This step up or step down electrical device is connected with ATC. This is often done by achieving adding of removing the turns within the power electrical device. An electrical device equipped with ATC and its equivalent diagram is shown in Figure 4. The notations I, U, n and y in the figure 4 indicates current, voltage, normalization of the transformer turn ratio and transformer admittance respectively. P and S indicate primary and secondary sides of the electrical device. This paper can solely alter OLTC that has been wide utilized in voltage regulation for several decades.

Tapping for Primary Side of different secondary voltages:

Turns ratio (K) of designed transformer,

$$\frac{N2}{N1} = \frac{V2}{V1}$$

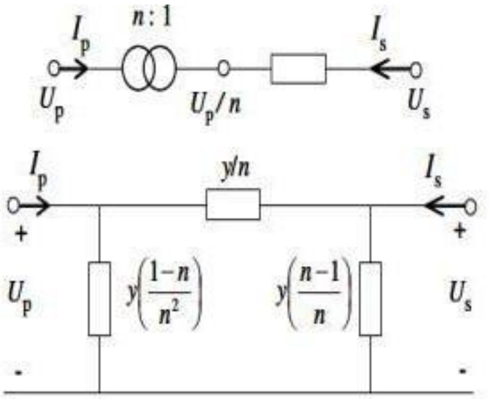
ULB < U1 < UUB (3-4)

where,

ULB = Uset – 0.5UDB is the lower boundary voltage

UUB = Uset + 0.5UDB is the upper boundary

Uset is the set point voltage and UDB is the deadband.



OLTC representation and its equivalent diagram.

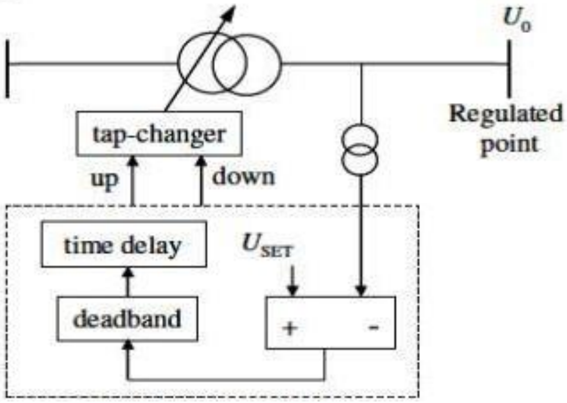


Fig 4. Basic OLTC arrangement

V. SWITCHING SEQUENCE OF AUTOMATIC OLTC

In oil-type OLTCs there are 2 styles of switch principles used. Tap pre choice while not current Diverter switch insert operation sort M. The diverter that consists of an arcing switch and a tap selector, and also the selector that consists of an arcing tap switch. Diverter sort OLTCs amendment tap in 2 steps. The operational switch time is 40- 50ms. The tap selector is operated through OLTC drive mechanism.

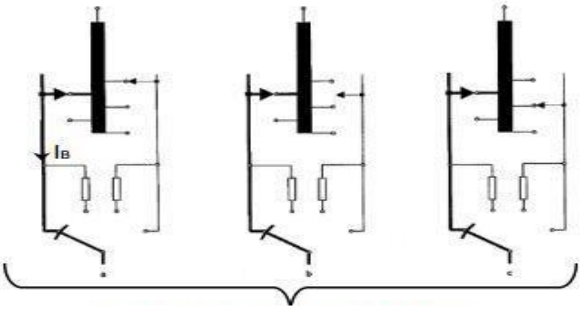


Fig 5. Tap pre selection without current

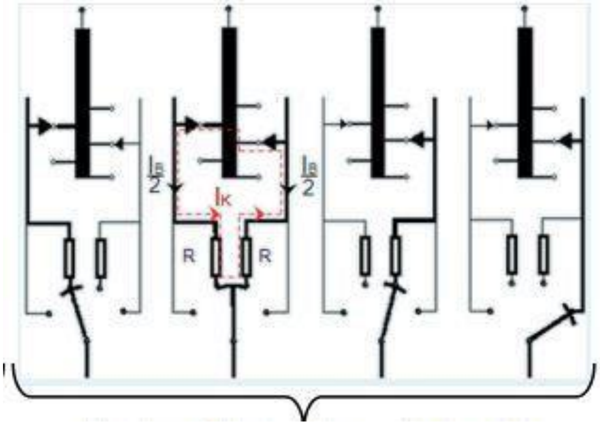


Fig 6. Diverter switch operation type M

A. *Automatic OLTC Control Principles*

When the transformer has an equal number of primary (input) and secondary (output) windings. The input and output voltage is equal. The most purpose of the automated transformer (AVR) for power electrical devices with on-load tap- changer (OLTC) is to stay the voltage on low voltage (LV) aspect of power transformer among a predetermined deadband. Such a principle features a major disadvantage that usually hastens an influence system voltage collapse. Merely aforementioned, once an electrical device has an equal range of winding activates the first (input) and secondary (output), the input and output voltage ought to be equal. By adding or subtracting the quantity of activates the secondary, the output voltage will be modified – up or down, respectively. Instead of physically dynamic the quantity of turns, the turns magnitude relation will be altered by dynamic the situation of the physical affiliation to the secondary. Transformers typically have multiple locations (known as “taps”) for affiliation to the secondary to regulate the output voltage. The automated AVR measures the voltage at receiving aspect bus bar UB, with within the dead band. The deadband is usually symmetrical around ΔUset as shown in Figure 7. Deadband ought to be set to a price shut to the ability transformer’s OLTC voltage step. Typical setting is seventy fifth of the OLTC step. Throughout traditional operational conditions the conductor voltage UB, stays among the deadband. In this case no actions are going to be taken by the AVR. The timer can run as long as the measured voltage stays outside the inner deadband. If this condition persists for longer than a predetermined time, the suitable LOWER or RAISE command can be issued. If necessary, the procedure is recurrent till the conductor voltage is once more at intervals the inner deadband. The most purpose of the time delay is to stop excess OLTC operations because of temporary voltage fluctuations. The time delay may additionally be used for OLTC co-ordination in radial distribution networks in order to decrease the range of excess OLTC operations. This could be achieved by setting an extended time delay for AVRs set nearer to the top shopper and shorter time delays for AVRs set at higher voltage levels.

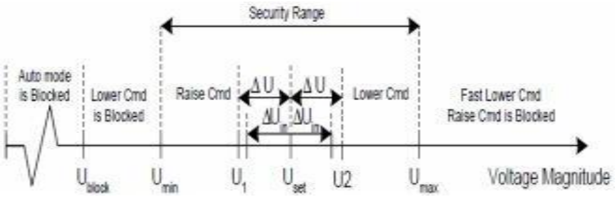


Fig 7. AVR voltage scale for automatic voltage control

Automatic On-Load Tap-Changer Control of parallel transformers can be made according to three different methods:

1. Reverse Reactance method
2. Master ñ Follower method
3. Circulating Current method

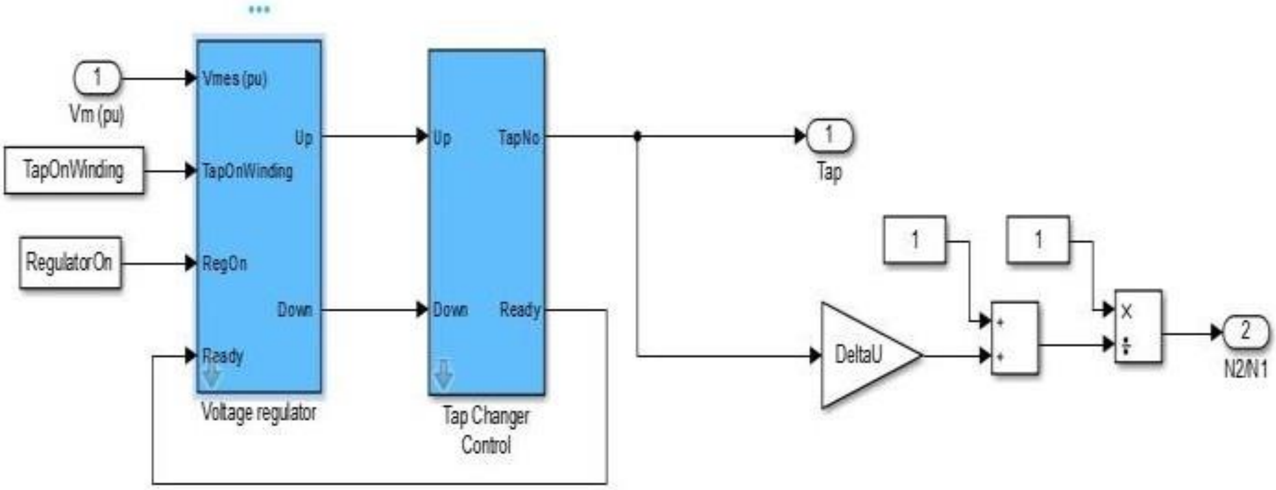


Fig 8. Voltage regulator and Tap changer control

B. Selection of Load Tap Changer(LTC)

The choice of a selected OLTC can meet out the subsequent technical likewise because the prices. Due to operating and testing of all conditions of the associated electrical device windings are fulfill. Basically, the security margins might be unconcerned for OLTCs designed, tested, elite and operated in accordance with IEEE and IEC standards are most reliable. To pick out the correct OLTC the following datas ought to be seen seriously

- ✓ MVA-rating
- ✓ Connection of tap winding (for Y, Δ or single part connection)
- ✓ Rated voltage and control vary
- ✓ Range of service tap positions
- ✓ Rated voltage and control vary
- ✓ Lightning impulse and power frequency voltage of the Insulation level to ground
- ✓ Internal insulation

The following OLTC operational information could also be derived from this information:

- Rated through-current: Iu
- Rated step voltage: Ui
- Rated step capacity: civil time= Ui × Iu

and also the applicable tap changer may be determined as follows:

- ✓ OLTC kind
- ✓ Basic affiliation diagram
- ✓ Range of poles
- ✓ Tap selector size/insulation level
- ✓ Nominal voltage level of OLTC

If necessary, the subsequent characteristics of the tap changer ought to be checked:

- Contact life
- Breaking capability
- Short-circuit current (especially to be checked just in case of part shifting applications)
- Overload capability

VI. SIMULATION MODEL OF OLTC REGULATING TRANSFORMER

In this design, 3Φ 2 winding 120/25 kV, 47 MVA OLTC control power electrical device is used for transferring the facility. These OLTC electrical device connections are high voltage Y-ground (Yg) and low voltage delta(Δ). The on load tap changer (OLTC) uses a tap winding (regulating winding) serial with winding 1(Yg) to vary the U1 voltage in 16 ΔU steps from tap -8 to +8 (17-positions).

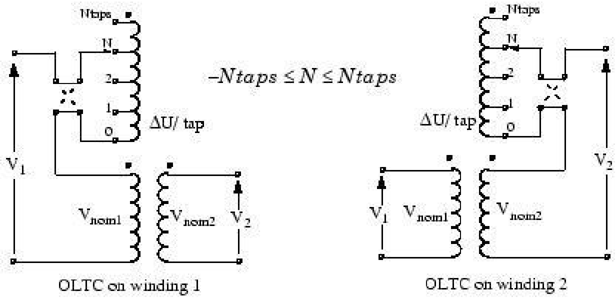


Fig 9. One phase of regulating transformer

–Ntaps ≤ N ≤ +Ntaps. The voltage ratios on the two windings are:

$$Winding\ 1: \quad \frac{V_2}{V_1} = \frac{1}{(1 + N \cdot \Delta U)} \times \frac{V_{nom2}}{V_{nom1}}$$

$$Winding\ 2: \quad \frac{V_2}{V_1} = (1 + N \cdot \Delta U) \times \frac{V_{nom2}}{V_{nom1}}$$

Tap position zero to correspond to nominal voltage magnitude relation. The electrical device voltage magnitude relation U2/U1 (p.u) is given by:

$$\frac{U2}{U1} = \frac{1}{1 + tap\ position\ \times \Delta U}$$

where, -8 ≤ tap position ≤+8.

In automatic mode, (voltage regulator 'on'), the signal applied at the Vm input is monitored and also the transformer asks for a tap amendment if:

abs(Vm - Vref) > deadband/2 throughout a time t > delay.

Voltage step 16 per tap = 0.01875 p.u

Initial tap position = -4

Tap choice time = 3 ~ 10 s

Tap transient time = 40ms ~ 60 ms

Transfer resistance = 5 ohm

Voltage regulator = 'on' mode

Vref= 1.04 p.u

ΔU = 0.0375p.u

Delay time = 1s

A. Block Model of OLTC Regulating Transformer

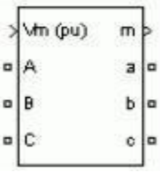


Fig 10. Block Model of 3Φ 2 winding Transformer

This Block Model of OLTC control electrical device The Block model of 3Φ two winding electrical device with OLTC is shown in figure 10. The dominant voltage is given to the automated on load tap dynamic device. This can be done by reactive power from the receiving tap of power electrical device. Depends upon the electrical device banks the reactive power is injected through block model shown in figure 10. Though the control electrical device doesn't offer the maximum amount flexibility and speed as power-electronics primarily based FACTS, it will be thought- about as a basic power flow controller. This block model is FACTS primarily based power electrical device. This can be used rather than mechanical electrical device. This model doesn't deals with commutation of FACTS devices. The control electrical device is sometimes associated with a bearing system that regulates voltage at the electrical device terminals (side 1 or side 2) or at a remote bus. Such a bearing system is provided in the Three-Phase OLTC control electrical device (Phasor Type) block. The m is that the tap position output. Then connect at the Vm input of the block a Simulink signal that is typically the magnitude of the positive-sequence voltage (in pu) to be controlled, however it may be any signal. The system can regulate mechanically the tap position till the measured voltage Vm is adequate the reference voltage Vref per the block menu. The transformer could be a physical phenomenon kind regulator. Every time a tap amendment is needed, the regulate sends a pulse either to the Up or Down input of the tap Changer Controller.

The regulator can kindle a tap amendment if |Vm – Vref| >Deadband/2 throughout a time t > Delay Where: Vref, Deadband, and Delay are parameters of the transformer.

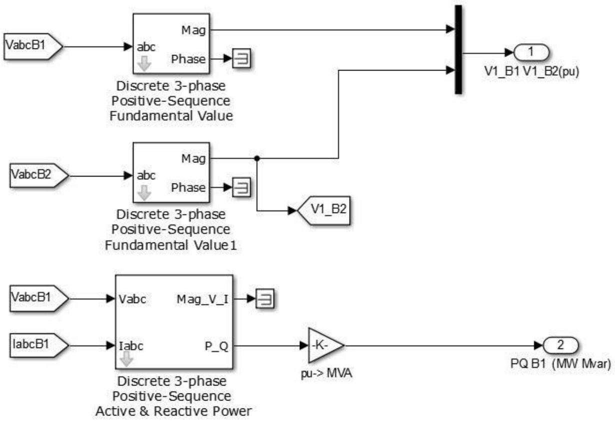


Fig 11. Signal Processing Block Diagram of OLTC Regulating Transformer (Voltage signal & Active and Reactive power signal)

For the correct control voltage the first and secondary tap winding is meant. Typically the AVR regulates voltage at the secondary tap of the power electrical device. The management methodology is primarily based on a step by step principle. The Vm is that the management pulse that is given to the FACTS based OLTC. Depends the management pulse, the FACTS primarily based 3 phase 2 winding electrical transformer acts as step up or step down electrical device. Because of the high speed shift devices the electrical device changes the voltages quickly. This cause a heating drawback within the electrical device. To scale back heating problems the electrical device needs correct cooling system. Therefore tap positions needs nitrogen based cooling devices. This increased the life time of tap changing positions.

VII. MATLAB SIMULATION OF OLTC REGULATING TRANSFORMER

For changing the tap position on the primary and secondary. The MATLAB simulation shown in figures 12 and 14.

For simulation the breaker switch the electrical condenser bank is injected reactive power to the facility transformer. K position (green color), tap positions (red color), bus voltage B1 (blue color) Bus voltage B2 (yellow color) p.u conditions, active power (MW) and reactive power (MVar) from high voltage aspect also are shown within the result figures 13 and 15. By victimization the breaker switch the electrical condenser bank is injected reactive power to the facility transformer. By victimization this matlab simulation models, OLTC changes the power transformer's turns magnitude relation. That the changes within the tap position produce variation within the secondary aspect voltage. Every step typically represents a amendment of ±1.25 you tired of low voltage aspect. Figures 12 and 14 the tap dynamical positions in high voltage winding respect with the secondary load changes. H.V winding of power electrical device is modified 230500/√3 ± 8×1.25% (17 positions) in each step changes ±2881V.

According to [sud2], "*Voltage regulation is performed by varying the transformer turn ratio. This is obtained by connecting on each phase, a tapped winding (regulation winding) in series with each 120/sqrt(3) kV winding. Nine (9) OLTC switches allow selection of 8 different taps (tap positions 1 to 8, plus tap 0 which provides nominal 120kV/25 kV ratio). A reversing switch included in the OLTC allows reversing connections of the regulation winding so that it is connected either additive (positive tap positions) or subtractive (negative tap positions). For a fixed 25 kV secondary voltage, each tap provides a voltage correction of +/-0.01875 pu or +/-1.875% of nominal 120 kV voltage. Therefore, a total of 17 tap positions, including tap 0, allow a voltage variation from 0.85 pu (102 kV) to 1.15 pu (138 kV) by steps of 0.01875 pu (2.25 kV)*"

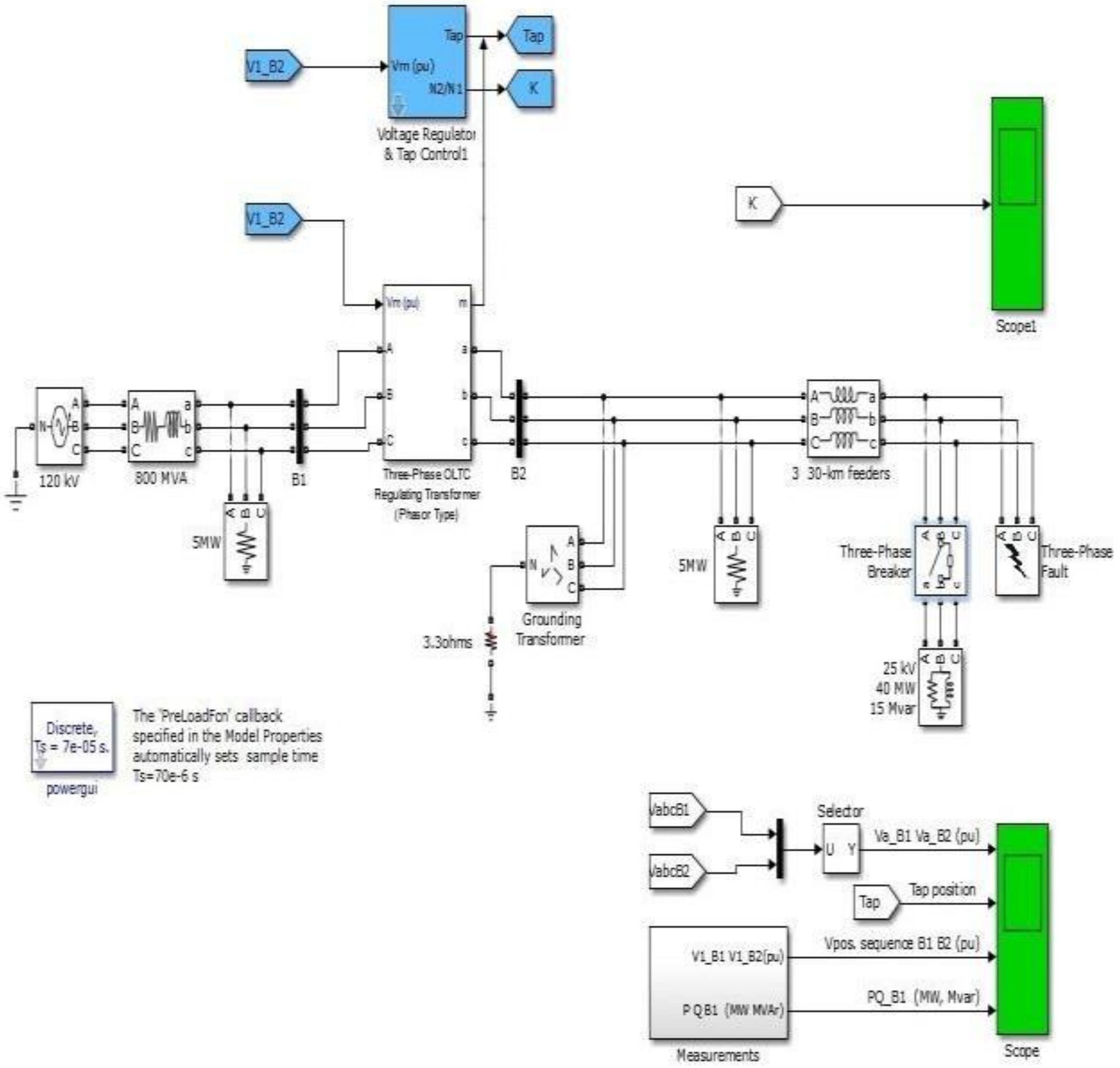


Fig 12. MATLAB Simulation of OLTC Transformer for 40MW 15 MVAR- Breaker open

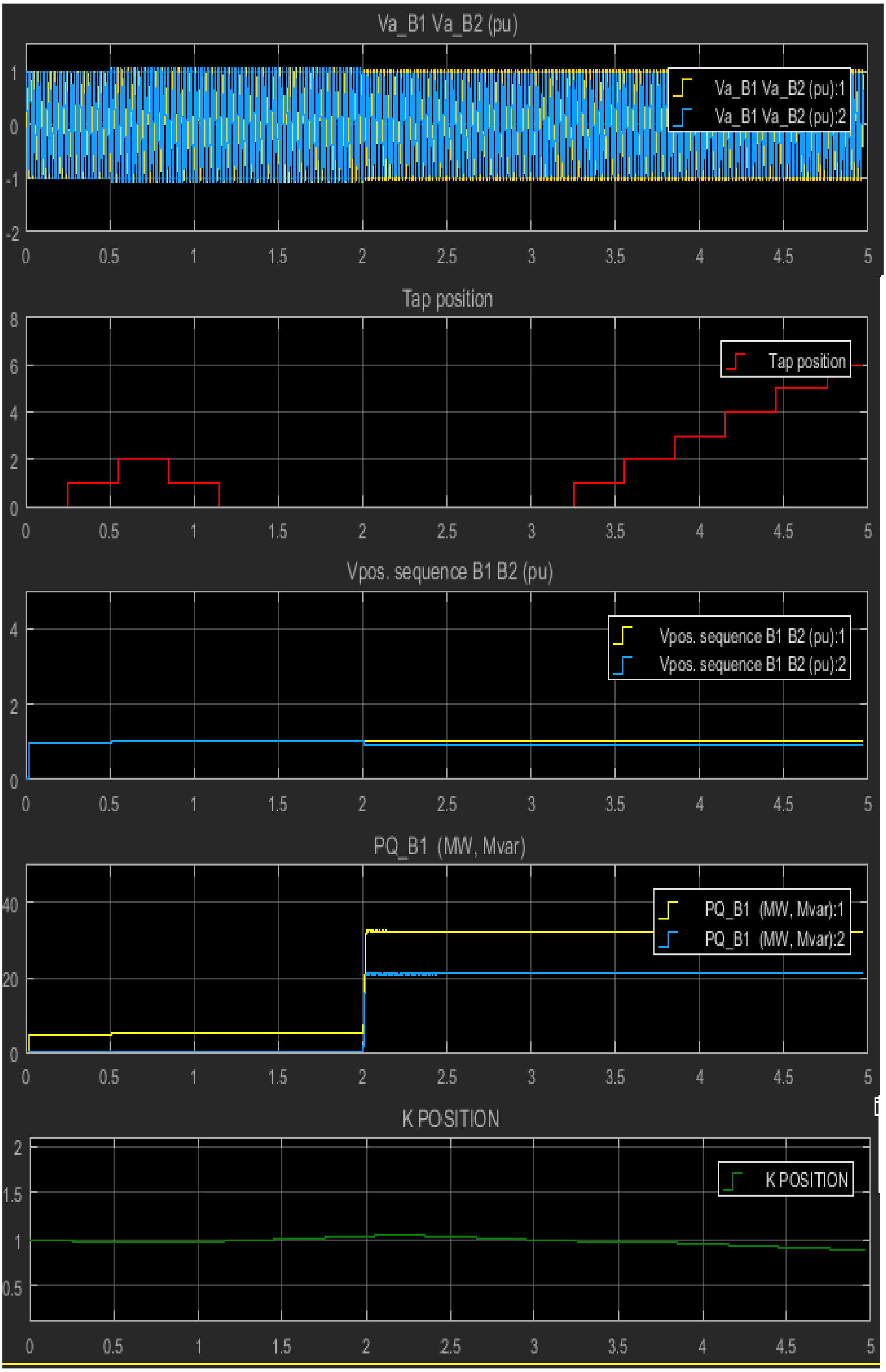


Fig 13. Simulation results of OLTC Transformer for 40MW 15 MVAR- Breaker open

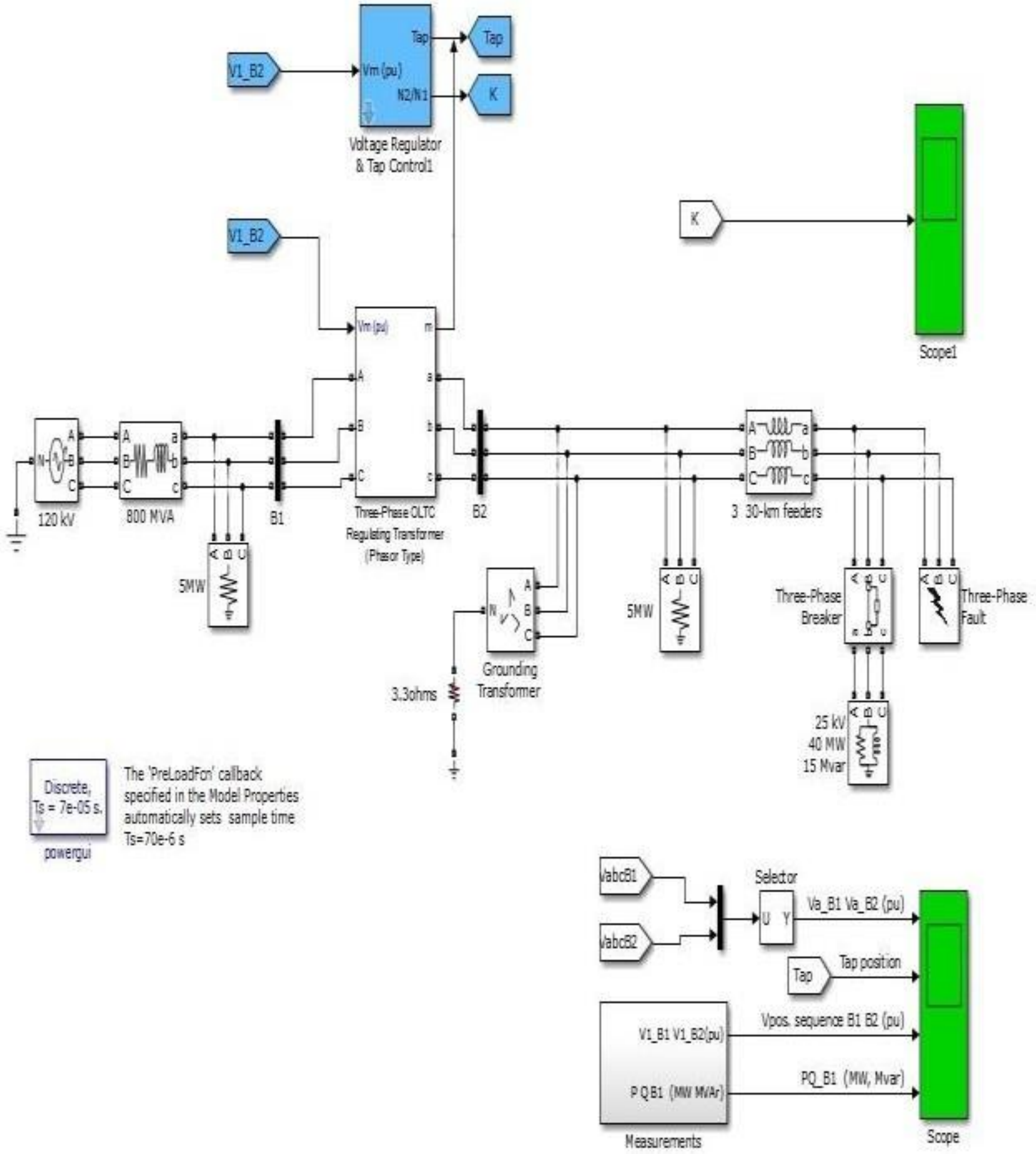


Fig 14. MATLAB Simulation of OLTC Transformer for 40MW 15 MVAR- Breaker closed

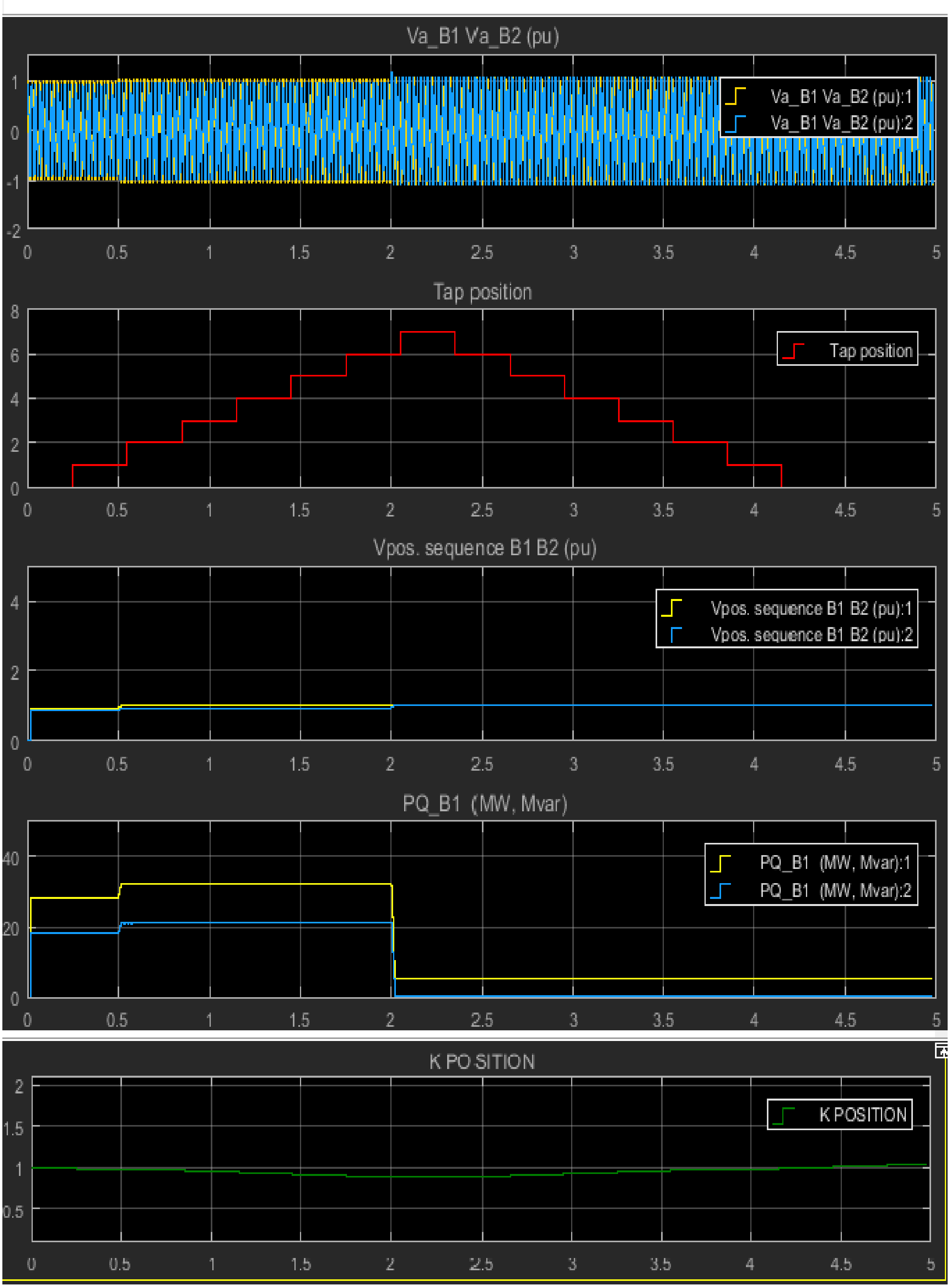
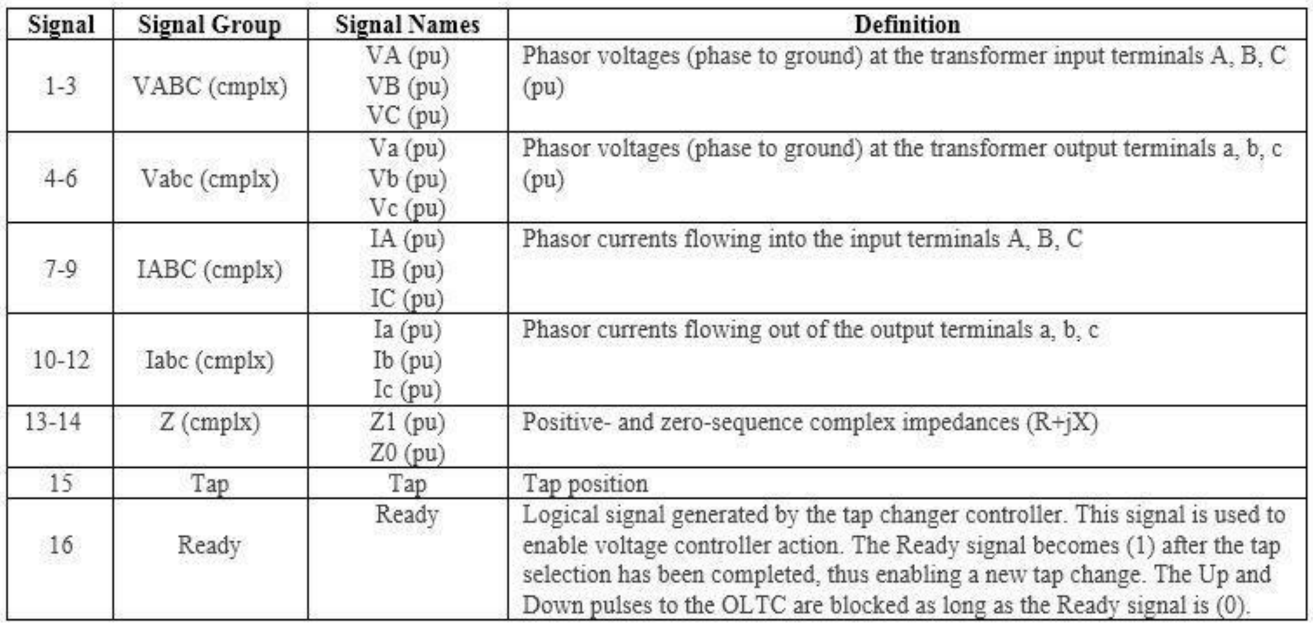


Fig 15. Simulation Results of OLTC Transformer for 40MW 15 MVAR- Breaker closed

Automatic voltage control using OLTC	Mechanical Tap Changer
Arcing problem is reduced	Arcing problem during tap changing
Power electronic switch is used for tap changing	Mechanical switch used for tap changing
Maintenance and service cost is low	Maintenance and service cost is high
The stability improves and quick response	Stability is not appropriate
Switching time is less	Switching time is more compared to Automatic OLTC

Table 1. Comparison between conventional Tap changer & Automatic Voltage Control of load using OLTC



Signal	Signal Group	Signal Names	Definition
1-3	VABC (cmplx)	VA (pu) VB (pu) VC (pu)	Phasor voltages (phase to ground) at the transformer input terminals A, B, C (pu)
4-6	Vabc (cmplx)	Va (pu) Vb (pu) Vc (pu)	Phasor voltages (phase to ground) at the transformer output terminals a, b, c (pu)
7-9	IABC (cmplx)	IA (pu) IB (pu) IC (pu)	Phasor currents flowing into the input terminals A, B, C
10-12	Iabc (cmplx)	Ia (pu) Ib (pu) Ic (pu)	Phasor currents flowing out of the output terminals a, b, c
13-14	Z (cmplx)	Z1 (pu) Z0 (pu)	Positive- and zero-sequence complex impedances (R+jX)
15	Tap	Tap	Tap position
16	Ready	Ready	Logical signal generated by the tap changer controller. This signal is used to enable voltage controller action. The Ready signal becomes (1) after the tap selection has been completed, thus enabling a new tap change. The Up and Down pulses to the OLTC are blocked as long as the Ready signal is (0).

Table 2. Simulink output (m) vector signals

VIII. CONCLUSION

This paper described the performance of on load tap changing transformer (OLTC). The use of power semiconductor devices, as a triac, insulated gate bipolar transistor (IGBT) which allowed the development of quick operating OLTC regulators which is also helpful in fixing other problems in the ac mains, like flicker and sags. The long transmission line is needed reactive power injection so the reactive power injection (Q) using capacitor bank through three phase breaker. Depends upon the breaker position on and off the reactive power is injected through the line. The reactive power (Q) is injected through transformer and it is controlled the Real power (P). Depends upon the reactive power (Q) injections the transformer tap position has to be increased or decreased. The tap position output is used to adjust the primary winding or secondary winding of the transformer. This is done by using FACTS devices. So the transformer is act as a step up or step down transformer.

So the conclusion of the project is the mechanical tap position is replaced by using OLTC- FACTS devices, the output is simulated using MATLAB was implemented. This brings better savings for the end user.

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