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ANALYSIS OF CIRCUIT BREAKER POLE RECLOSING OF 765 KV TRANSMISSION LINE

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ABSTRACT

The insulation level of extra high voltage (EHV) and ultra high voltage (UHV) ac systems is largely determined by the magnitude of switching over voltages. The reliable operation of the electrical system is determined by the amplitude, duration and frequency of the transient voltages. This paper presents the study of transient voltages and currents introduced in the 765 kV systems due to the circuit breaker pole reclosing. The effect of single-pole reclosing, double-pole reclosing as well as reclosing of poles of all the three-phases is presented in detail. The variation of current during arcing period and arcing resistances is also investigated. The effect of circuit breaker pole reclosing on the flow of active and reactive power at different buses in the system is also investigated. A test system having generation, loads, transmission lines and connected to the utility network is modeled in MATLAB/Simulink environment.

KEYWORDS: Arcing Period, Arcing Current, Arcing Resistance, Circuit Breaker Pole Reclosing, 765 Kv Transmission Line, Utility Grid

1. INTRODUCTION

Transmission lines in the power system are an interface between the generating stations and distribution systems [1]. It provides the path to transfer electrical power from central generating stations to load centers [2]. The analysis of electromagnetic transients arising in EHV/UHV power networks gives necessary information about the possible stresses on the different network components, which will determine their proper design and limits of operation [3]. The single-phase to ground faults are the most frequent to occur on EHV transmission systems and most of the faults are transient in nature induced by lighting [4]. These faults, may be cleared by opening the circuit breaker (CB) poles of the faulted phase at each end of the transmission line [5]. In a three-phase transmission line, when one phase is open circuited, a fraction of total pre-fault power flow is maintained between the two ends through the two healthy phase wires. For restoring the three-phase supply and improvement of the transient stability, fast auto-reclosing of these tripped CB poles should be carried out with minimum time delay [6].

The study of transients during switching and reclosing of the circuit breaker poles has been reported in the literature in the recent years. Om Prakash Mahela *et al.* [7], presented the analysis of capacitor cells failure due to circuit breaker pole discrepancy in RRVPNL power grid. The study of the electrical stresses imposed on line circuit breaker of a 500 kV, AC expansion of the FURNAS transmission system is presented in [8]. The test results of single-phase switching (SPS) on the AEP-765 kV system are presented in [9]. The purpose of the tests was to determine the self-extinction times of large secondary arc currents in circuits with varying degrees of SPS compensation.

This paper presents the study of transient voltages and currents introduced in the 765 kV systems due to the circuit breaker pole reclosing. The effect of single-pole reclosing, double-pole reclosing as well as reclosing of all the three-phases is presented in detail. The variation of current during arcing period and arcing resistances is also investigated. The effect of circuit breaker pole reclosing on the flow of active and reactive power at different buses in the system is also investigated.

This paper is divided into four sections. Starting with an introduction in section 1, the section 2 covers the test power system model used for the analysis of reclosing of 765kV circuit breaker. The simulation results and their discussion are presented in section 3. Finally, the concluding remark is included in the section 4.

2. PROPOSED POWER SYSTEM MODEL

The test system for the analysis of the circuit breaker pole reclosing of 765 kV transmission line is shown in Figure 1. The test system has two voltage levels of 13.8 kV and 765 kV. A synchronous generator of 4200 MVA and 13.8 kV is connected to the generator bus (BG). The test system is connected to the utility network at bus B-2. The details of three transmission lines in the system are given in Table 1 and 2. The details of transformer between buses BG and B-1 are given in Table 3. The loading status of all loads L-1 to L-5 is given Table 4. The measurement of three-phase voltages and currents are taken from the bus BM. The measurement of arcing current and arcing resistance is taken at bus B-3 for phase-A.

Table 1: Test System Transmission Line Parameters

S. No.	Attributes	Value
1	Positive sequence resistance R1 (**Ω**/km)	0.01165
2	Zero sequence resistance R0 (**Ω**/km)	0.2676
3	Positive sequence inductance L1 (H/km)	0.8679e-3
4	Zero sequence inductance L0 (H/km)	3.008e-3
5	Positive sequence capacitance C1 (F/km)	13.41e-9
6	Zero sequence capacitance C0 (F/km)	8.57e-9

Table 2: Transmission Line Length

Transmission Line	Line Length (Kms)
TRL-1	200
TRL-2	100
TRL-3	100

Table 3: Transformer Parameters

Transformer	MVA	kV-High	kV-Low	HV Winding		LV Winding	
				R (pu)	L (pu)	R (pu)	L (pu)
T-1	4200	765	13.8	0.002	0.08	0.002	0.08

Table 4: Loading Status

Load	Quantity of Load	
	P (MW)	Q (Mvar)
L-1	200	0
L-2	0.80	200
L-3	0.80	200
L-4	0.80	200
L-5	0.80	200

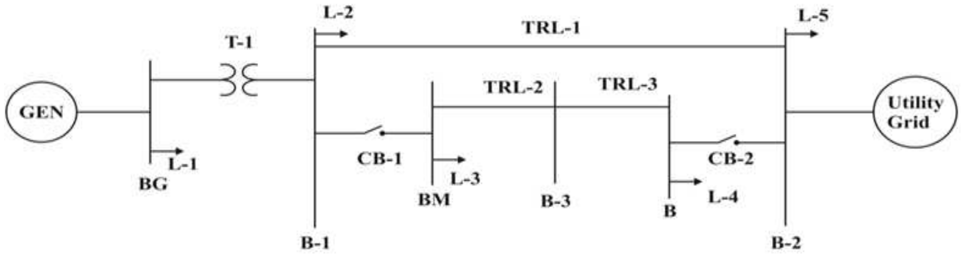

Figure 1: Proposed Model of Power System for Study of CB Pole Reclosing

3. SIMULATION RESULTS AND DISCUSSION

The power system model shown in Figure 1 is simulated in Matlab/Simulink environment. The switching of poles of circuit breakers CB-1 and CB-2 are carried out at 4^{th} and 34^{th} cycles simultaneously. Initially the CB poles are closed and opened at 4^{th} cycle and reclosed at 34^{th} cycle to study the effect of reclosing of the circuit breaker poles on the system voltage and load current.

3.1. Single-Pole Reclosing

The poles of phase-A of circuit breakers CB-1 and CB-2 are simultaneously opened at 4^{th} cycle and reclosed at 34^{th} cycles during the simulation. The voltage of all the phases is shown in Figure 2 and currents are shown in Figure 3. The arcing current is shown in the Figure 4 and the arc resistance is shown in the Figure 5. As indicated in the Figure 2, the voltage of phase of which the circuit breaker pole is operated first reduces during the arcing period and then becomes zero because the measurement bus is on the isolated section of the system. During the period of opening of the pole and reclosing of the pole, the supply is not available on the measurement bus. As indicated in the Figure 3, the current in the phase of which the circuit breaker pole is opened and reclosed first increases during the arcing period and then reduces to the zero. The current again restored after reclosing of the circuit breaker pole. The current and voltage transients exist in the system after the reclosing of CB pole. The arcing current exists only for 3 cycles. The arc resistance reduces to zero at the time of initiation of arc and then increases within 0.3 seconds. The power generation and consumption at different buses is provided in Table 5 and the flow of active and reactive power at each bus is provided in Table 6.

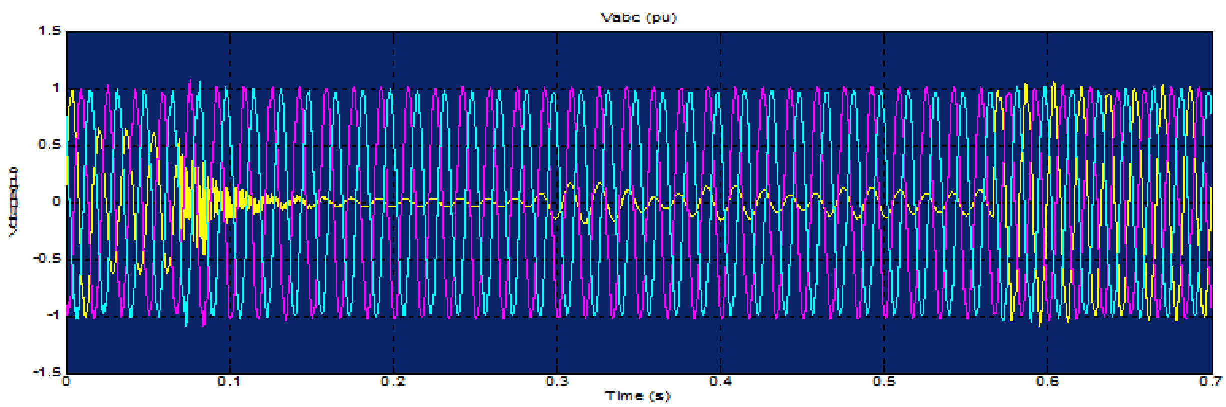

Figure 2: Three-Phase Voltages with Single-Pole Reclosing

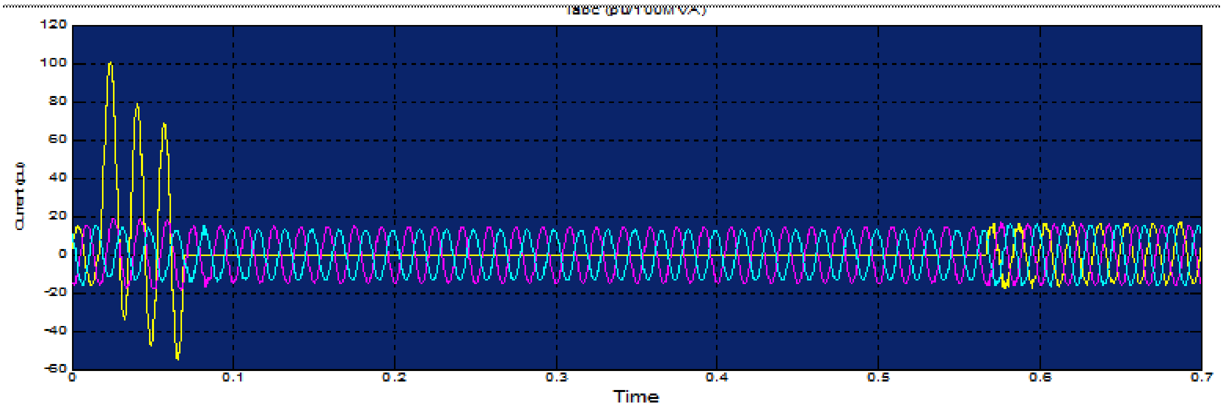

Figure 3: Currents of All Phases with Single-Pole Reclosing

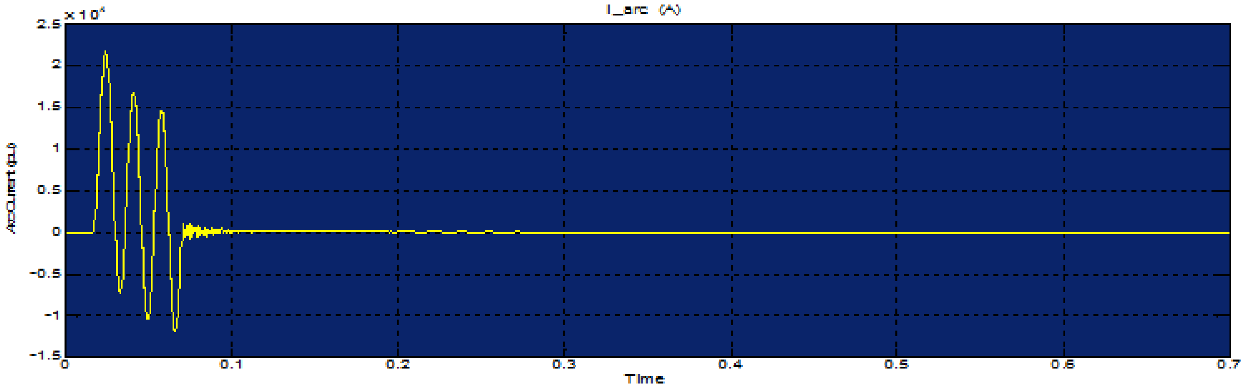

Figure 4: Variation of Arcing Current

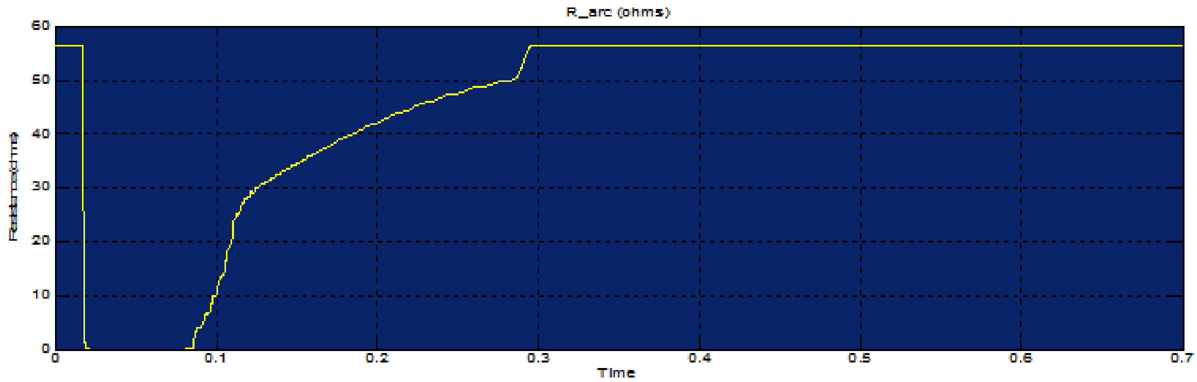

Figure 5: Variation of Arc Resistance

Table 5: Bus Voltage and Power Data

Bus No.	Voltage (pu)	Generation		PQ Load		Impedance Load		Remark
		P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	
B1	$0.995\angle 9.59^\circ$	0	0	0	-0	5.85	-41.05	PV Bus
B2	$1.0\angle 0^\circ$	-2981.8	245.93	0	0	1.70	-45.63	Swing Bus
B3	$1.002\angle 4.77^\circ$	0	0	-0	-0.01	0.02	-297.72	PV Bus
BG	$1.0\angle -13.79^\circ$	3220.0	225.57	0	0	204.2	4.20	PV Bus

Table 6: Load Power Flow Data

Power Flow from Bus	Power Flow to Bus							
	B1		B2		B3		BG	
	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
B1	-	-	1500.61	31.09	1500.66	-117.04	-3007.12	127.00
B2	-1491.78	220.39	-	-	-1491.70	71.17	-	-
B3	-1496.78	244.55	1496.12	53.17	-	-	-	-
BG	3015.80	221.37	-	-	-	-	-	-
Total Losses P=26.46 MW Q=851.71 Mvar								

3.2. Double-Pole Reclosing

The poles of phase-A and phase-B of circuit breakers CB-1 and CB-2 are simultaneously opened at 4th cycle and reclosed at 34th cycles during the simulation. The voltage of all the phases is shown in Figure 6 and currents are shown in Figure 7. The variation of arcing current and the arc resistance is same as shown in Figure 4 and Figure 5 respectively. As indicated in the Figure 6, the voltage of phase-A first reduces during the arcing period and then becomes zero because the measurement bus is on the isolated section of the system. The voltage of phase-B reduces at a rate slower than that of the phase-A and voltage of phase-C remains unchanged. As indicated in the Figure 3, the current in the phase-A first increases during the arcing period and then reduces to the zero and current of phase-B remains unchanged during arcing period and then decreases to zero. The current and voltage in phases-A and B is again restored after reclosing of the circuit breaker pole. The current and voltage transients exist in the system after the reclosing of CB pole and magnitude as well as the period of the transients is larger than that for the single-pole reclosing.

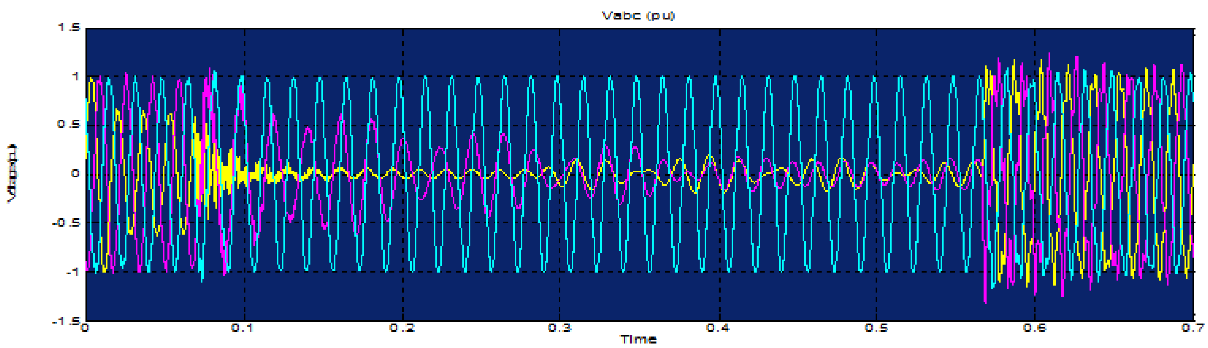

Figure 6: Three-Phase Voltages with Double-Pole Reclosing

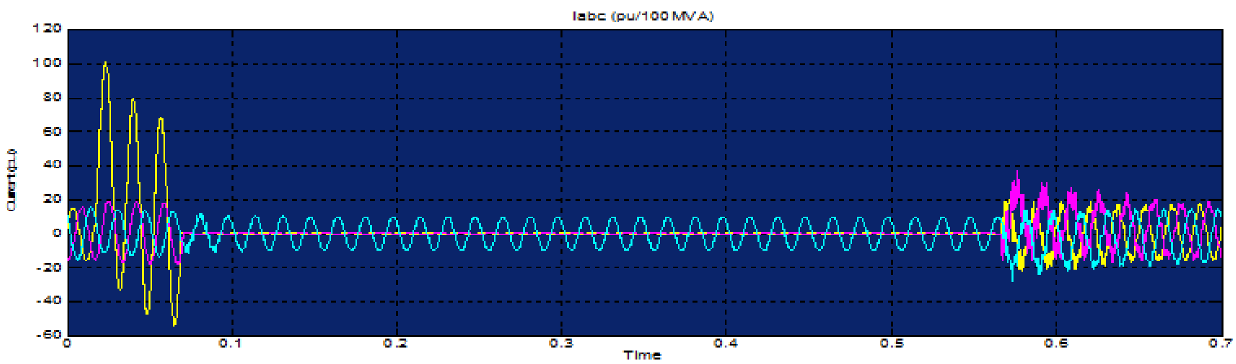

Figure 7: Currents of All Phases with Double-Pole Reclosing

3.3. Three-Pole Reclosing

The poles of all the three phases of circuit breakers CB-1 and CB-2 are simultaneously opened at 4th cycle and reclosed at 34th cycles during the simulation. The voltage of all the phases is shown in Figure 8 and currents are shown in Figure 9. The variation of arcing current and the arc resistance is same as shown in Figure 4 and Figure 5 respectively. As indicated in the Figure 8, the voltage of phase-A first reduces during the arcing period and then becomes zero because the measurement bus is on the isolated section of the system. The voltage of phase-B and C reduces at a rate slower than that of the phase-A. As indicated in the Figure 9, the current in the phase-A first increases during the arcing period and then reduces to the zero and current phase-B and C remains unchanged during arcing period and then reduces to zero. The current and voltage in all the three phases are again restored after reclosing of the circuit breaker poles. The current and voltage transients exist in the system after the reclosing of CB pole and magnitude as well as the period of the transients is larger than that for the single-pole reclosing and double pole reclosing.

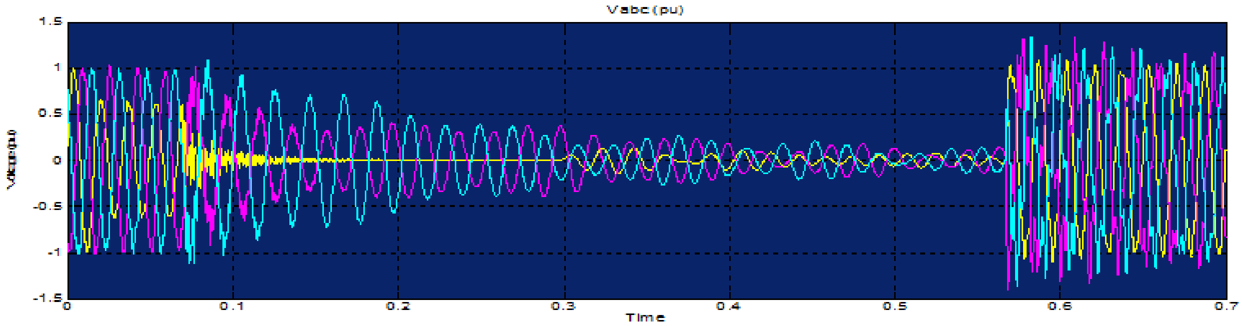

Figure 8: Three-Phase Voltages with Three-Pole Reclosing

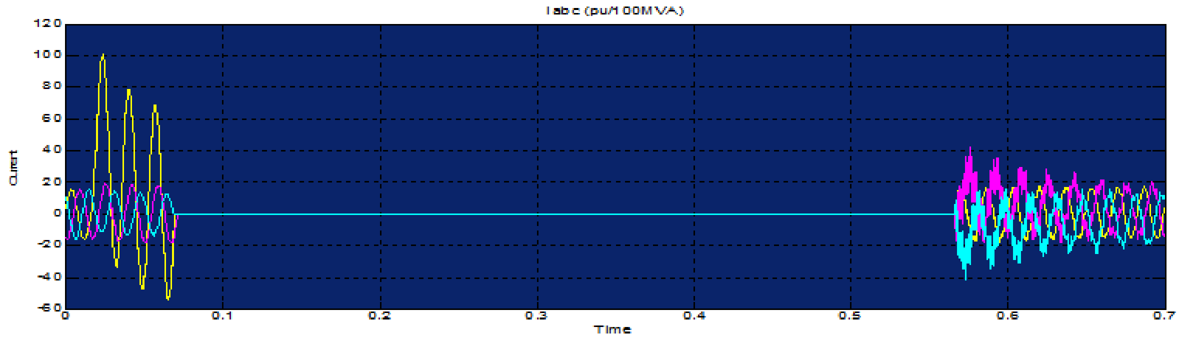

Figure 9: Currents of All Phases with Three-Pole Reclosing

CONCLUSIONS

In this paper, the analysis of voltage and currents of the 765 kV transmission line due to the reclosing of circuit breaker poles is carried out. The analysis is carried out for single pole reclosing; double pole reclosing and simultaneous reclosing of all the three phases. The variation of current during arcing period and arcing resistance is also discussed. From the developed study, it can be concluded that reclosing of the circuit breaker pole in the 765 kV transmission line produces the transients in both voltage and currents. The magnitude of transient voltage and current as well as transient time is maximum for three pole reclosing and minimum for single pole reclosing.

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APPENDICES

BIOGRAPHIES

Naveen Gaur received Engineering Diploma, from Govt. polytechnic college, Ajmer, India in 2000. He received B.E. Electrical from Rajasthan Institute of Engg. And Tech. Jaipur, India in 2004 and M. Tech. (Power System) from Bhagwant University, Ajmer, India, in 2014.

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Ram Niwash Mahia received his B.E. degree in Electronics instrumentation and Control Engineering from Govt. Engineering College Bikaner, Bikaner, India and his M.E. degree in Control and Instrumentation under Electrical Department from Delhi College of Engineering, Delhi, India in 2007 and 2009, respectively. He is pursuing Ph.D. degree in Information Communication and Technology from Indian Institute of Technology Jodhpur, Rajasthan, India, since August-2011. From March 2010 to july-2011, he was an Assistant Professor with the Department of Electronics Instrumentation and Control Engineering, Global Institute of Technology, Jaipur, Rajasthan, India. His research interests include control of multi-agent systems, nonlinear control, robust control and its applications for uncertain systems.

Om Prakash Mahela was born in Sabalpura (Kuchaman City) in the Rajasthan state of India, on April 11, 1977. He studied at Govt. College of Engineering and Technology (CTAE), Udaipur, and received the electrical engineering degree from Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, India in 2002. He received M. Tech. in 2013. He is currently pursuing PhD from Indian Institute of Technology, Jodhpur, India.

From 2002 to 2004, he was Assistant Professor with the RIET, Jaipur. From 2004 to 2013, he has been Junior Engineer-I with the Rajasthan Rajya Vidhyut Prasaran Nigam Ltd. (RRVPNL), India. Presently he has been Assistant Engineer with RRVPNL. His special fields of interest are Transmission and Distribution (T&D) grid operations, Power Electronics, Power Quality, Renewable energy sources and Load Forecasting. He is an author of 22 International Journals and 15 Conference papers. He is a Member of IEEE. He is Member of IEEE Power & Energy Society. Mr. Mahela is recipient of University Rank certificate from MPUAT, Udaipur, India, in 2002 and Gold Medal for M. Tech. in 2013..