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Understanding Reactive Power and Its Importance in Power Systems

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***Abstract:** The main intent and purpose of this paper is to flaunt the rudimentary and homespun idea of reactive power on electrical power systems. Electrical machines such as motors and generators require reactive power for the production of magnetic field. Transformers and transmission lines too obligatory reactive power while they bring up with resistance and inductance contend with the flow of current. The Voltage profile must be uplifted to push this power through line inductance. Suitable reactive power when not used can cause contemplative black-outs.*

***Key words:** Reactive power, Voltage profile, Black-out.*

I. INTRODUCTION

Reactive power delineates the unobtrusive energy drift in an AC system emanating from the augmentation of electrical and magnetic fields. It is the amalgamation of sustained hasten transfer or 'real' energy swirl, affiliated with splattering or 'imaginary' energy swirl. Reactive power has its incipience in the phase alternation allying these two signal profiles. So long as a device squanders factual power in cognation to that the voltage and current signal profiles are in phase with one another, the device squanders naught reactive power. So long as the current demarcated into a device hangs back to the voltage, it squanders reactive power. The consignment of reactive power squandered by the device be influenced by the phase alternation allying the voltage and current.[1-2] Excluding this, while the median in time is being enumerated, the mean active power exists precipitating a net excretion of energy from one location to a further, on the contrary the mean reactive power is zero, disregarding the state of the system or network of the system. With the understanding that of reactive power, the consignment of energy streamlined in one direction is indistinguishable or one and the same to the consignment of energy flowing in the contradictory direction. [3] By this means, the reactive power is neither engendered nor imbibed. But, in actuality we estimate reactive power losses, introduce so many equipments for reactive power compensation to diminish the cost and consumption of electricity.

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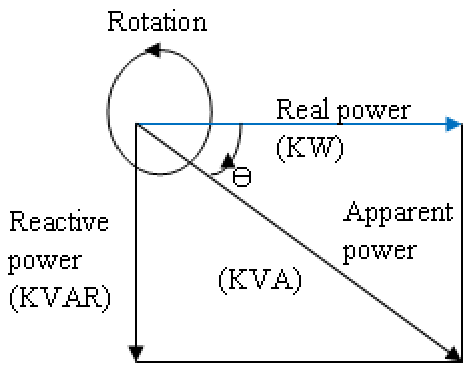

Fig.1 Representation of Real, Reactive and Apparent powers through power triangle.

Fig 1 represents the real power, reactive power and apparent power through power triangle. Here, Θ stands for power factor angle. Let us perceive the reactive power with some real life illustrations.

Fig 2. A man trying to fill water in water drum.

Presume, I wish to fill a vast water drum with water, one bucket at a time. The Only approach is to climb a ladder, humping a bucket of water and disgorging the water into the drum as displayed in figure Fig 2. I ought to go down the ladder to procure additional quantity of water once I fill up the drum. In this cycle of climbing up and coming down the ladder, the amount energy utilized to go up is more than the energy required for coming down.

NO work is done if the I had climbed the ladder with an empty bucket, came down with the same empty bucket since, the energy for upward and downward motion is the same. A requisite amount of energy is utilized even though no work is done. It is clear that, carrying nothing either way i.e., the energy that it takes to go up and down a ladder requires no real power but reactive power. It requires both real power and reactive power to go up a ladder carrying something and come down without carrying anything. Other Examples:

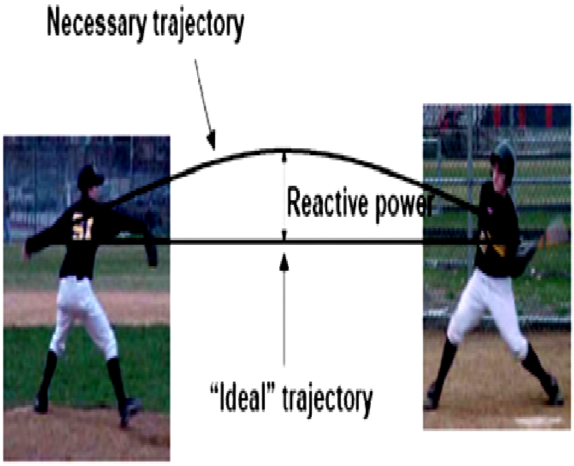

Fig 3. The Loft in a base ball throw

Fig 3 displays the lofting of a ball in a base ball game. The power required to loft the ball is reactive power and the power required to reach the batsman is real or useful power. The upward component of the trajectory does not contribute to getting the ball any closer to the batter, but without it the ball won't get there.

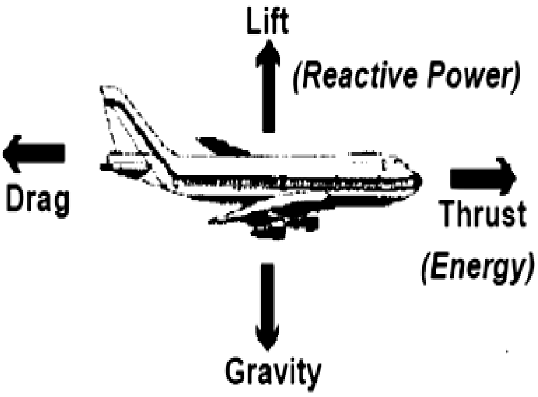

Fig 4. Lift of an Airplane

Suppose, an airplane is ready to fly and is moving on run way with some velocity. The engines are designed such that a huge quantity of air flows over the wings rapidly. The air flows downwards to the ground generating an upward force called Lift. Lift does not get you any closer to the destination, but without it you are driving, not flying. The energy used to Lift the plane is reactive power and the energy used by the plane to reach destination is real power.

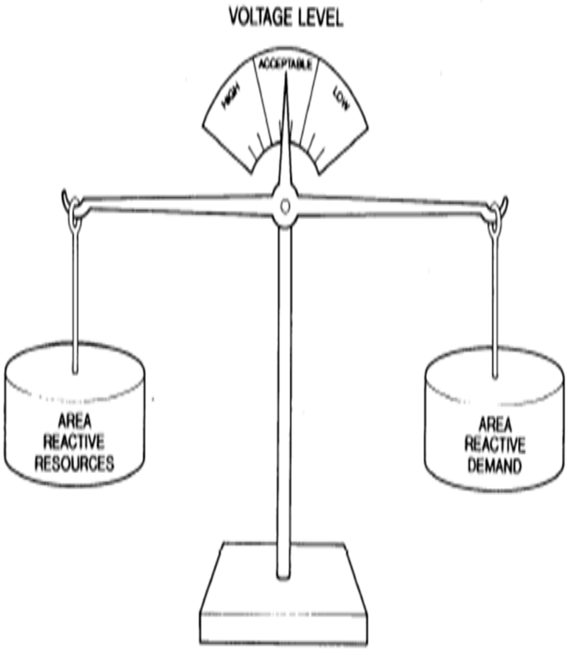

Fig 5. Balance between reactive power sources and sinks

Fig 5 displays the necessity of balance between sources and sinks of reactive power. Reactive power relates to the flowing capacity in the system that does not have any particular function. It results from energy storage components in the power grid (inductors and capacitors). Reactive power has vigorous consequences on the system voltages. In order to prevent voltage issues, the grid must be regulated and a reliable and safe transmission network must be maintained. The reactive power level has an impact on the voltage failure. Improper reactive power induces unnecessary magnetization in the core, eddy currents, excessive heat generation, thermal insulation loss and unintended dead short circuit. Poor reactive power results in a wide distance between input and output, resulting in inadequate magnetization, resulting in incorrect work being performed. [4-5]

II. REACTIVE POWER LOCATION

Fig 6. Reactive power transmission for long distances

Fig 7. Reactive power transmission for closer distances

The above figures Fig 6 and Fig 7 represents the transmission of reactive power for longer distances and closer proximity respectively. It is obligatory that Reactive power unfailingly located in closest proximity to the consumption. It cannot be effectively transmitted across long distances or through power transformers due to high line load losses or I^2R losses. The Closer the consumption the lesser is the loss due to reactive power transmission.

III. IMPORTANCE

Voltage management in an electrical power network is critical for the proper operation of electrical power equipment to avoid harm such as overheating of generators and motors, minimize transmission losses and preserve the device's capacity to withstand and prevent voltage failure. Reduced reactive power allows voltage to decrease whereas increased reactive power allows voltage to increase. A voltage failure can occur when the device tries to service a far higher load than the voltage could sustain. It is obligatory to increase current when reactive power supplies lower voltages. This is because to maintain the power supplied during voltage drops. It further increases the voltage drop by causing the system to consume additional reactive power. Line outages may happen if the current is increased too much beyond the limit, overloading the other lines. This causes cascading failures. When the voltage falls too far, certain generators can immediately detach to secure themselves. The voltage failure happens where a change in load or reduced supply or transmitting equipment allows the voltage to decrease, resulting in a greater decline in the reactive power from capacitor and line charging and causing more decrements in voltage. When the voltage reduction occurs, this may allow additional elements to trip, resulting in more voltage reduction and load failure. The consequence of all these rapid and uncontrollable voltage declines is that the device cannot provide the reactive power required to satisfy the reactive power requirements.[6-7]

IV. NECESSITY

Voltage protection, control and efficient reactive power management are two components of a common operation that both promotes stability and enables transactions through transmission networks. The voltage is constrained or regulated by governing reactive power production and integration on AC power system. There are three explanations why it is important to regulate reactive power and monitor voltage. Firstly, reactive power absorbs transmission and generation energy. To optimize the volume of real power that can be transmitted through a congested transmitting network, reactive control flows must be optimized. Similarly, reactive power generation will restrict the real power capacity of the generator. Secondly, all consumer and power system appliances are equipped to work with in a variety of voltages, typically around ±5 percent of nominal voltage. At very less voltages, certain forms of devices work very poor, light bulbs produce fewer lighting. Induction motors may get overheated and be impaired and some electronic devices may not function at all. The destruction and shortened life time of equipment occurs due to high voltages. Lastly, transferring reactive power to the transmission network incurs actual loss of electricity. All power and electricity must be provided to account for these losses. The main objective of a power system network is to maintain tolerable voltage levels through the overall transmission and distribution even during contingencies. It is also obligatory to mitigate overflow of real power, thus minimizing the real power loss.[6-7]

V. BLACK-OUTS

A variety of metrics may be used to determine the efficiency of electrical energy supply. Nonetheless, the availability of power and the amount and length of interruptions are also the most significant issues. The demand for inductive reactive power rises at the same pace when electricity usage is high. In this moment, a more inductive reactive control is given by the transmission lines (which are well charged). There are inadequate local sources of capacitive reactive fuel. Further reactive fuel will be provided from power plant generators. They could be completely loaded already and reactive input from more remote locations will be supplied. Reactive power transfer can fill the lines further, thus growing reactive electricity. The customer's voltage will start to fall. Local voltage regulation of automobile transformers contributes to an rise of current and this in effect reduces voltage changes in wires. This results in decreased voltage. This cycle will at one moment be like an earthquake, which decreases the voltage to zero. During the meantime, because of excessive low voltage, most power plant turbines are shut off and, inevitably, the condition gets worse. Inadequate reactive capacity to break voltage has led to significant blackouts around the globe. The blackouts of July 2, 1996, and August 10, 1996 on the West Coast, triggered a voltage collapse in the United States.[8] While the outage was not due to a breakdown in voltage in the United States and Canada, as this concept has historically been used by the engineers in power systems, the final report of the Task Force says that insufficient reactive power was a issue and overestimation of the reactive dynamic performance of device generation is also typical among major US failures.[8] Reactive power demand was extraordinarily high due to large volumes of transmissions from locations, like Canada, across Ohio which required electricity to be imported to meet local demand. Nevertheless, the reactive power supply was poor because other plants were inaccessible and probably because certain plants did not generate sufficiently.

VI. LIMITATIONS

- Reactive power must be proximity to consumption as shown in Fig 7.
- Must not travel to the farther locations as shown in Fig 6.
- Reactive power supplies are directly related to the capacity to produce actual or usable electricity.

VII. CONCLUSION

- Real power is the useful quantity of electricity supplied to drive a generator, heat a house, or light an electrical lamp.
- Reactive power is necessary for transferring active power through the transmission and distribution grid to the consumer.
- Reactive control is needed to retain the voltage to transmit active power (watts) through the transmission line.
- The active power cannot be transmitted if the voltage is not enough
- Reactive power is often used to supply sufficient voltage thresholds required for active power to do useful work.
- If the reactive power is not sufficient, the voltage decreases, and the required power cannot be pushed over the lines by loads.

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