**Problem Statement:**

As electricity is the backbone of all development and innovation, Sudan's electricity situation is a challenge that needs to be tackled with excellent efficiency and using innovative solutions. According to governmental sources, the national unified electricity grid covers less than 40% of Sudan, more than 60% of this is residential demand, 75% of power generated goes to the capital state; Khartoum state. Khartoum itself has a 66% connection percentage, while the 3rd and fourth states based on population density; South Darfur and North Kordofan have 2% and 5% connection percentage.

Electricity in Sudan has an average production cost of 18 cents; residential electricity is heavily subsidized and sold at a range of 1.8% to 19.4% of the production cost. Adding this to a usage increase of 10% annually; highest amongst neighbouring countries; means that inequality of electricity will only continue to grow, the top 1% earners in Sudan use 49% of electricity produced while the lowest 49% use only 21% of electricity produced. This situation needs a re-evaluation of the system used in Sudan to achieve a fast recovery and adaptation to modern models.

Sudan's system is a conventional system of centralized generation; the government uses a single system to generate electricity at far-away stations or dams; then it is distributed in the country. This system is dying in the world as the old equipment causes high maintenance const and reliability problems; it is a limitation to the addition of new demand areas. Old engineering and outdated system of management, as well as the efficiency concerns, cause Sudan to have an astronomical loss rate of 25%. Combining this with its environmental concerns and lack of renewable energy utilization make it one to be changed.

The distributed generation where we generate where we will consume and have smaller grids, smaller generation and smaller transportation of electricity is an alternative worth considering. Here we a flexible system, easy to maintain, efficient, modular, reliable, economically efficient, and above all environmentally responsible because of the renewable energy cornerstone, it stands on.

When looking into Sudan and its high number of villages and lack of major cities we can see that microgrids present a great model of distributed generation to Sudan's rural areas. Microgrids are a variation of smart grids where we create small scale grids to work on villages, islands, and small residential areas, which can work as a standalone islanded grid or can be grid-connected. It uses distributed energy sources and renewable energy sources to generate electricity locally and then fulfil the local demand and use storage units for night demand and fault cases. As it is a smart grid then a grid management system is needed, advancements in control present machine learning as a robust technique to control profoundly different systems to control the full cycle from generation to consumption. Reinforcement learning is our technique of choice due to its usage in sequential control.

**Microgrids**

A microgrid is a collection of energy production units and consumers (load) placed near each other to reduce the cost of transport and control. These grids use Renewable Energy Resources (RESs) as the production units those include Solar Energy production units (Photovoltaic units PVs), Wind production units (Wind Turbines), Biomass units as well as Energy storage system. Load supplied by the Microgrid can be critical load (industrial factories, hospitals, schools)and non-critical load (houses). The supply between this type of loads merely depends on the mode of operation the Microgrid is operating in; dual-mode operation on-grid where we connect the Microgrid to the primary utility grid in normal conditions. The other mode is off-grid or known as (islanded )mode where the microgrid switch to be operating without the back up of utility grid due to shortage or disturbance in the primary grid. In some scenarios of switching mode, the non-critical load is deactivated from the Microgrid until we reach a stable status. Microgrids components from a control unit, inverters, batteries help in determining the supply-demand profile of the Microgrid. We connect The different Microgrids to a primary controller alongside the main grid. This controller receives the supply-demand information of each Microgrid and the mode, on-grid or off-grid.

There are various techniques to apply to microgrids to obtain stability; As a beginning, we have the Master-slave technique where one of the DERs acts as the master of the control and the rest of the DERs is supposed to follow as the slave. This technique's biggest flaw is that the failure of the master means the failure of the whole Microgrid, and it was going out of the system. Next, we have Centralized techniques where we have a main central controller, which all DGs report to it, its inflexible, unreliable(mention one of them). Last, we have decentralized technique where each DERs has an individual Local controller that reports to the central microgrid controller it is more flexible and efficient. Any failure in one of the DERs does not affect the functioning of the rest of the Microgrid. We will give further details about this technique and its usage in the coming chapters.

**Reinforcement Learning:**

The high-level control between the microgrids will be handled by a reinforcement learning algorithm, working as a black box that trades when needed deciding then with which Microgrid and with what price in order for our microgrids to achieve equilibrium. Reinforcement Learning is a field of Machine Learning where the problem it solves is an environment that is affected by an algorithm controlled agent. The agent takes an action that changes the environment, then the agent sees the environment as an observation, and receives a reward on the "goodness" of the action it last took. We use this to optimize its policy which decides which action to take based on which state we are in, and a state is a unique set of values that the observation returns that fully or partially describe our environment. We use the concept of a Markov decision process, where this state is sufficient to predict the future. Through time, the actions taken by the agent traverse the state space until we reach our goal state or goal reward. The optimal policy will do this in the best path possible as we will later introduce concepts that push towards a faster goal-reaching policy.

In the context of our project, we will create an environment that simulates several microgrids with full generation and load profiles. We will then create an agent that will choose the action of buying or selling electricity when our generation and stored electricity are insufficient to our load. It will also choose the price of the transaction in order to achieve the maximum economic gain from the trading situations.

**Research Objectives**

This thesis proposes working in Microgrid islanded mode and introduces a Reinforcement Learning algorithm to manage an energy trading process between neighbouring grids to achieve optimality (equilibrium) in production. The research aims to propose a system for off-grid power management and trading between different microgrids by using expected power production (supply), consumption (demand) forecasting, and power storage information. We will apply machine learning techniques in specific reinforcement learning and deep reinforcement learning to solve the trading process. We will test multiple algorithms on our created environment and will find the best algorithm to solve the problem.

**Research Questions**